AD-780 638

BLAST HAZARDS OF THE LIQUID PROPELLANTS
LCO AND LN_2O

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URS Research Company

Prepared for:

Air Force Rocket Propulsion Laboratory

January 1974

SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER AFRPL-TR-74-7	2. GOVT ACCESSION NO. 	3. RECIPIENT'S CATALOG NUMBER *AD-780 638*
4. TITLE *(and Subtitle)* Blast Hazards of Liquid Propellants LCO and LN$_2$O		5. TYPE OF REPORT & PERIOD COVERED Final Report
		6. PERFORMING ORG. REPORT NUMBER URS-7309-12
7. AUTHOR(s) Chuck Wilton A.B. Willoughby		8. CONTRACT OR GRANT NUMBER(s) F04611-73-C-0053
9. PERFORMING ORGANIZATION NAME AND ADDRESS URS Research Co. 155 Bovet Road San Mateo CA 94402		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 323430
11. CONTROLLING OFFICE NAME AND ADDRESS Director of Science and Technology (AFSC) Air Force System Command Edwards CA 93523		12. REPORT DATE Jan 1974
		13. NUMBER OF PAGES 155
14. MONITORING AGENCY NAME & ADDRESS*(If different from Controlling Office)* Air Force Rocket Propulsion Lab LKDP Edwards CA 93523		15. SECURITY CLASS. *(of this report)* UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Liquid Propellants
Propellant Hazards
Propellant Blast Environment

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)* A limited test program was conducted to obtain preliminary explosive yield data for the propellant combination of liquid carbon monoxide and liquid nitrous oxide, under conditions which simulate credible failure in a future test facility.

During the course of the program ten tests were conducted using mixtures of these propellants in both liquid and gas phases and another five tests were conducted using mixtures of liquid or gaseous carbon monoxide and air. Propellant weights ranged from about 50 to 800 lbs.

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The results from the tests show that the propellant combinations has significant explosive potential, but that it is much more difficult to initiate an explosion in this combination than in other liquid propellant combinations studied previously. Explosions were obtained in only two of the five tests in which liquid phase mixtures of both propellants were used but no explosions were obtained with the other test conditions.

Based on the limited data available, an interim estimate is made of the explosive yield potential to be used for the future test facility, until additional tests and analyses can be conducted to provide a better value. Recommendations are included for a test program to accomplish this.
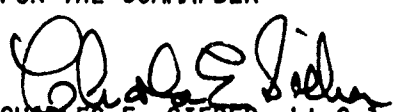
FOREWORD

This report was prepared by URS Research Company, San Mateo, California, under Air Force Contract F04611-73-C-0053 which supported the Air Force Rocket Propulsion Laboratory program evaluating the blast hazards of the propellant combination, liquid carbon monoxide, and liquid nitrous oxide.

The URS support included establishing the overall design of the program, analyzing the test data, providing ordnance and instrumentation consulting, and writing the final technical report. This program and the AFRPL test program were directed by Captain Charles R. Mastromonico and Mr. Forrest S. Forbes of the Air Force Rocket Propulsion Laboratory, Edwards, California 93523. This report has been reviewed and is approved.

FOR THE COMMANDER

CHARLES E. SIEBER, Lt Colonel, USAF
Chief, Liquid Rocket Division

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Section 1

INTRODUCTION

During the calendar year 1973, the Air Force Rocket Propulsion Laboratory (AFRPL) conducted a limited program to obtain preliminary explosive yield data for the propellant combination of liquid carbon monoxide (LCO) and liquid nitrous oxide (LN_2O). These data were needed by the Air Force Weapons Laboratory (AFWL) in order to perform a system hazard analysis as required by Mil-STD-882.

The primary objective of the AFRPL program was to obtain explosive yield data for mixtures of LCO and LN_2O under conditions which simulate credible failures at a future AFWL test facility.

Section 2
SCOPE OF BLAST HAZARDS STUDY

A complete evaluation of the hazards of any given propellant com-
bination includes determination of the blast, thermal, toxicity, and
fragmentation characteristics for all of the credible failure modes of
the system or systems using the given propellant combination. The pres-
ent program was limited to a preliminary evaluation of the blast hazard
of the specified propellant combination for a particular application.

When a propellant combination is in widespread use and is known to
have a significant blast hazard, determination of its specific blast
characteristics requires an extensive test program supported by theoret-
ical studies. In brief, such a program involves first, determining all
of the ways in which the propellants can interact, i.e., come into con-
tact with each other; second, selecting generalized test configurations
which reasonably model each of the significantly different types of pro-
pellant interactions; and third, conducting a series of tests for each
generalized configuration varying the important parameters of the spe-
cific interaction mode.*

In searches of the literature prior to the start of this program no
significant quantitative information was found regarding the potential
blast hazards of the LCO/LN_2O propellant combination. For this reason,
and because the information was needed only for one particular applica-
tion, an extensive test program such as that described above was con-
sidered premature. Rather it was concluded that the first step should
be to determine whether the LCO/LN_2O propellant combination had any

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* Project PYRO (Ref. 1) was an example of such a comprehensive program
for the propellant combinations of $LO_2/RP1$, LO_2/LH_2, and $N_2O_4/50\%$
UDMH-50% N_2H_4 . It included 270 tests with weights ranging from 200
lbs to 100,000 lbs.

2-1

significant blast hazard for the range of propellant interactions cred-
ible for the specific application. If the results showed little signi-
ficant hazard, no further work would be required. If, however, the re-
sults indicated a significant hazard further work might well be neces-
sary to define the specific hazard more precisely.

From a review by the AFRPL of the conceptual designs of the future
test facility (actual system design had not been finalized), two major
failure modes were initially considered: tank rupture; and line or
component failure. Based on the extensive experience the AFRPL has had
with liquid propulsion systems, leaks, line rupture, valve failure, and
related problems have been found to be far more prevalent than gross
failure of ground based propellant tanks. This experience, coupled with
the need for immediate data and consideration of available equipment,
led to the decision to limit the test program to an evaluation of line
and component failures.

Section 3

TEST PROGRAM DESIGN

GENERAL

In selecting the test configurations of concern in this program, it
was convenient to use the same basic rationale (but not the same overall
program) as used in Project PYRO for the cryogenic propellants. This
rationale is that regardless of the details of how the propellants are
released, propellants undergoing similar interactions (mixing) will lead
to mixtures having similar explosive properties. In other words, any
time two propellant masses interact with each other in the same fashions
and with the same constraints, the explosive yield as a function of time
after initial contact will be the same.

It was further shown in Project PYRO that the most convenient way
to characterize the interaction of two propellants was to first estab-
lish what is called the boundary conditions, i.e., the environment cr
surroundings present during initial contact and subsequent mixing of the
propellants.

Upon consideration of the proposed facility the two basic sets of
credible boundary conditions which were selected for investigation were
semi-confined and unconfined. The semi-confined propellant interaction
mode is designed to investigate the case where the propellants are par-
tially confined by the combination of two impinging streams and the
ground surface. It also includes the case where some vertical confine-
ment is present simulating a spill in an instrumentation trench or other
depression in the ground surface.

The unconfined propellant interaction mode is designed to investi-
gate these cases where one or both of the propellants are ejected forc-
ibly into the ambient air.

For each of these basic interaction modes there is a number of other parameters which potentially can have a significant effect on yield. As was done in Project PYRO these can be conveniently divided into the following general classes.

1. Specific properties of propellants,
2. Initial conditions of propellants, and
3. Ignition conditions.

Although many of the specific properties of the propellants (such as density, viscosity, heat capacity, conductivity, boiling and freezing points, heats of fusion and vaporization, etc.) are expected to be important in the mixing process, they are not subject to variation except in large discrete steps (that occur when propellant type changes), i.e., they are fixed once the propellant type and initial conditions are specified. Accordingly the only specific propellant property that entered into the test program design was the propellant type. Two basic cases are of concern - CO/N_2O and CO/air. Since liquid phase mixtures of CO/N_2O are credible, this propellant combination was considered far more important than the CO/air mixture which can only occur in the gas phase. The reasons for this are discussed later under the subsection on Initial Conditions.

The initial conditions, i.e., the conditions at the time of first contact of one propellant with the other, consist of

1. State of propellants,
2. Spatial distribution of propellants, and
3. Velocity distribution of propellants.

The ignition conditions consist of

1. Time of ignition (from first contact of propellants), and
2. Nature of ignition source.

Each class of conditions is discussed in the following, leading to the selection of the variables of potential interest for the test program.

INITIAL CONDITIONS

State of Propellants

Depending on the manner of their release, the propellants can be in the liquid state, gas state, or mixtures thereof. Of these three cases the liquid state is considered to represent by far the largest potential hazard. It has been shown in previous propellant studies (Ref. 1) that two cryogenic propellants of significantly different temperatures are able to mix extremely rapidly and thoroughly under many conditions because of the violent turbulence created by the boiling heat transfer. As a result they are able to create quite concentrated explosive mixtures. Gas phase mixtures of propellants can also explode, although because of their low densities they are much less hazardous near the point of the explosion than are condensed (liquid) phase explosions. They can, however, be as serious at long distance for the same total weight of material. However, it is very much more difficult to mix large quantities of material in the gas phase, in the proper proportions and in a reasonable period of time, to achieve the same result. In fact it is believed that the only practical way to accomplish this is to confine the gases totally.

It is also believed that no significant mixing of liquid phase and gas phase propellants can occur except in the gas phase because of the great density difference. Thus the liquid/gas mixture case would degenerate into the gas phase case.

For the above reasons the liquid phase case was selected for primary consideration in the design of the test program.

Spatial Distribution

In generalized terms the initial distribution of the LCO and LN_2O propellants can be described by:

1. the total weight (w);
2. the shape (with one or more variables); and
3. the position of the mass (with one or more variables).

In characterizing the shape and position variables of the propellants it is convenient to consider the semi-confined and unconfined interaction modes separately.

For the credible failure modes in the semi-confined case the propellants are released in narrow separate streams impinging on the ground surface either simultaneously or with one propellant leading the other.

Each impacting stream will create a spreading thin pool expanding initially with the velocity of impact. Maximum mixing should occur when the two streams are close together since this will result in maximum overlap of the two spreading pools. It also would be expected that for a given quantity of propellant, the larger the release orifice the greater the yield potential, since this results in a smaller pool and a more concentrated propellant mixture. Any additional confinement surface such as a circular vertical wall around the spreading pool should also increase yield for the same reason.

Thus, shape and position variables of concern for the semi-confined are the total weight of each propellant, the diameters of the release streams, the separation between the two release points, the time lag between release of the two propellants, and the type of additional vertical confinement if any.

For the unconfined case, the two propellants are again released in separate streams but in the absence of any major confining surfaces such as the ground surface. If the streams were simply ejected into free air it is difficult to see that much liquid/liquid mixing could occur even if the streams were directly opposed, i.e., impinging directly on each other - a case which is difficult to justify as being credible. Even gaseous mixing would likely be fairly slow because the streams would not expand very rapidly due to their high velocity. However, it is clearly credible to have many minor confinement surfaces such as piping, valves, gages, and tanks which could well serve to break up the two streams. With the streams broken up, gaseous mixing would be greatly enhanced, however significant liquid mixing still seems unlikely.

The credible condition of most concern, then, is that resulting from the two separate streams impacting on minor reflecting surfaces and breaking up into many smaller streams which mix with each other in the surrounding air volume. Clearly, the better dispersed each stream is, the better chance there is for rapid mixing. It is also clear that simultaneous release of the propellants should lead to maximum yields.

To characterize the breakup of the streams it seems reasonable to consider the primary stream as being broken up into many small streams or sprays which together have the same flow volume. Maximum mixing should occur when the two propellants are sprayed into the same general area. For experimental convenience separated spray nozzles were selected and oriented so that the center lines of the sprays from each propellant intersected at an angle of approximately 90 degrees.

Thus, the shape and position variables of concern for the unconfined case, are the total weight of each propellant, the total flow rate, the number of streams of each propellant (i.e., number of spray nozzles and their characteristics) and the separation of the release point (including the orientation of nozzles).

Velocity Distribution

For the semi-confined case, one of the major effects of velocity is in determining the time for release of the total quantity of propellants. As the velocity is varied the rate of pool spreading will also vary but the size of the pool when all the propellants are down will be essentially the same. It is anticipated that the higher velocities will create more splashing and thus tend to reduce the amount of liquid mixing. At the other limit, if the propellants are released too slowly a significant amount of boil off will occur before all the propellants are down. Because failure of the pressurization system is credible a wide range of velocities is also credible. Thus, the worst credible case is the lowest velocity that will keep boil off to a reasonable amount by the time all the propellants are down.

For liquid phase mixing in the unconfined case with multiple spray nozzles, a relatively high velocity seems desirable since this should tend to minimize the amounts of the propellants evaporated prior to the release of all the propellants and make the resulting mixture more dense. To eliminate the effects of ambient wind conditions at the test site (which must exceed 5 mph for toxicity safety considerations) the propellants were released within non-rigid, very thin, frangible enclosures.

AIR AND SURFACE CHARACTERISTICS

Since the system of concern is intended to be housed in a building, the air conditions of concern are, for practical purposes, still air at room temperature.

The characteristics of the surface of possible importance are those co trolling:

1. Heat transfer properties,

2. Porosity, and

3. Roughness.

The importance of heat transfer to the ground surface (assumed to be concrete) was determined during Project PYRO for LO_2/RP1, which have roughly the same density and temperature differences as the propellant combination LCO/LN_2O. The results indicated that, for a typical mixing condition, the rate of heat transfer between LO_2 and RP1 was between one and two orders of magnitude greater than that between LO_2 and concrete. (The difference was attributed to the break up of the liquid RP1 surface, giving a surface area in contact with LO_2 very much greater than with concrete.) Accordingly, the heat transfer characteristics of the underlying surface will not be considered further in the test design.

The other two parameters, porosity and roughness, are not likely to have any significant effects either, unless they take on extreme values, which is not assumed likely.

It is known that the various reactions of both gaseous CO and N_2O can be catalyzed or enhanced by a number of substances including metallic oxides and small amounts of water vapor. It is suspected that these effects may be of secondary importance in the present case where a powerful stimulus is used to initiate the explosion. However, these effects should be given some further consideration particularly if extremely low blast yields are obtained.

IGNITION CONDITIONS

With failure modes which lead to massive propellant spills, the time of ignition of a propellant mixture after the start of the mixing process has been demonstrated many times to be the most important single factor with regard to explosive yield. In the present case, however, where the credible failure modes are limited to line ruptures or other relatively

small orifice releases, it is anticipated that the time of ignition will likely be of less importance, particularly for mixing in the liquid phase. This is because the time for the propellants to mix is expected to be significantly shorter than the time to release the propellants. The time of ignition is still of concern, however, since it will control the amount of propellants, their shape, and to some extent their phase, i.e., liquid or gas.

The previously studied non-hypergolic liquid propellant combinations (LO_2/RP1, LO_2/LH_2) both showed extreme sensitivity to ignition. It was also found that their explosive yield was essentially independent of the nature of the ignition source so long as it was sufficient to ignite any portion of the mixture, even to burning. Accordingly, standard detonator caps were selected for the ignition source in the initial portion of the program. In later tests a squib (flame) source was also used.

SUMMARY OF PARAMETERS

In the foregoing sections the variables of concern for each basic test condition were identified and to the extent possible their anticipated effects were discussed. It was clearly not possible, nor even desirable, to try to cover all of these in the test program. In general, whenever one particular value of a variable was credible and tended to maximize the explosive yield, only this value of the variable was used.

For the semi-confined condition variations in the following parameters were eliminated. The fixed values used are given.

Area of release orifice - maximum credible area selected.

Separation between two release points - minimum credible separation.

Velocity of propellant release - minimum velocity with tolerable boil off.

Weight - one experimentally convenient value with tolerable boil off and measurable blast pressures for significant yields, on the order of 100s of lbs.

The variables remaining for the __semi-confined condition__ and their selected values are listed below:

__Type of vertical confinement__ - 2 values

- None

- Vertical wall to make shallow pool 3-ft in diameter.

__Time lag between release__ - 2 values

- Simultaneous

- Long enough so that one propellant is pooled before other is released. For experimental convenience, the LCO was pooled. For vertical wall case only.

__Time of ignition__ - 2 values

- When all propellants are down

- Later time selected to be as long as possible with tolerable boil off.

For the __unconfined condition__ variations in the following parameters were eliminated. The fixed values used are given.

__Time lag between release__ - simultaneous release only.

__Velocity__ - maximum credible value.

__Weight__ - one experimentally convenient value with measurable blast pressures for significant yields (on the order of 100s of lbs).

__Number of streams of propellant__ - to obtain maximum dispersion spray nozzles were used, with the number for each propellant varying from two to four.

__Flow rate__ - maximum credible value.

__Separation of release points__ - one value selected as ~12-ft.

The only variables remaining are:

<u>Type of propellant</u> - 2 values

- Simultanoues release of both propellants.
- Release of LCO only.

<u>Time of ignition</u> - 2 values

- When all propellants have been released.
- Later time to be selected on the basis of test results

TEST PROGRAM MODIFICATIONS

Because of the essentially unknown explosive behavior of the LCO/LN$_2$O propellant combination and the limited effort available for this program it was anticipated that many modifications would be made in the above outlined test program. As test results became available certain parameters wo'd turn out to be more or less important than expected making it desir.ble to reorient later tests. The biggest factor was the unexpected difficulty in obtaining proper ignition of the propellant mixture.

Another and equally important factor influencing the type of tests that were actually conducted was that the design of the particular system was evolving during the conduct of the program. For a time it appeared that there would be no need to consider the hazards of liquid phase mixing and effort was reoriented toward gas phase tests which were not included in the original program.

The net effects of the two above factors were: that a series of gas phase mixing tests were added to the program; one important subcase of the semi-confined condition was dropped from the program because of a redirection of effort; and less quantitative explosive yield data than expected were obtained from the tests that were conducted.

The subcase that was not investigated was the semi-confined case without vertical confinement. This case should, of course, result in a smaller hazard than the semi-confined case with vertical confinement. It is, however, a far more probable failure condition.

Section 4
SEMI-CONFINED TESTS

These tests were intended to investigate the interaction of the propellants when mixing occurs on the ground surface. Ground surface conditions of interest range from a flat horizontal surface with no vertical walls, to a surface with vertical walls high enough to contain all propellants. For reasons discussed earlier only the tests with vertical walls were run.

TEST CONDITIONS

The test configuration selected for this condition was a light weight aluminum cylindrical tank 3-ft in diameter and 3-ft high. The propellants were fed into the tank through two separate 1-1/2 in. diameter lines, one on each side of the tank. Initiation in the first few tests was provided by two detonators mounted on the tank walls at a height of 12 in., the height of the surface of the liquids if they are quiescent when all propellants are in the tank. In later tests, one of the caps was replaced with a squib. A sketch showing the tank and the locations of the filling lines and the detonators is given in Fig. 1.

In some tests the LCO was loaded into the tank first and after a three second delay, the N_2O was then loaded. In other tests both propellants were loaded simultaneously. In all cases the initiators were set to go off two seconds after fueling was completed.

A summary of the test conditions for each of the tests is given in Table 1.
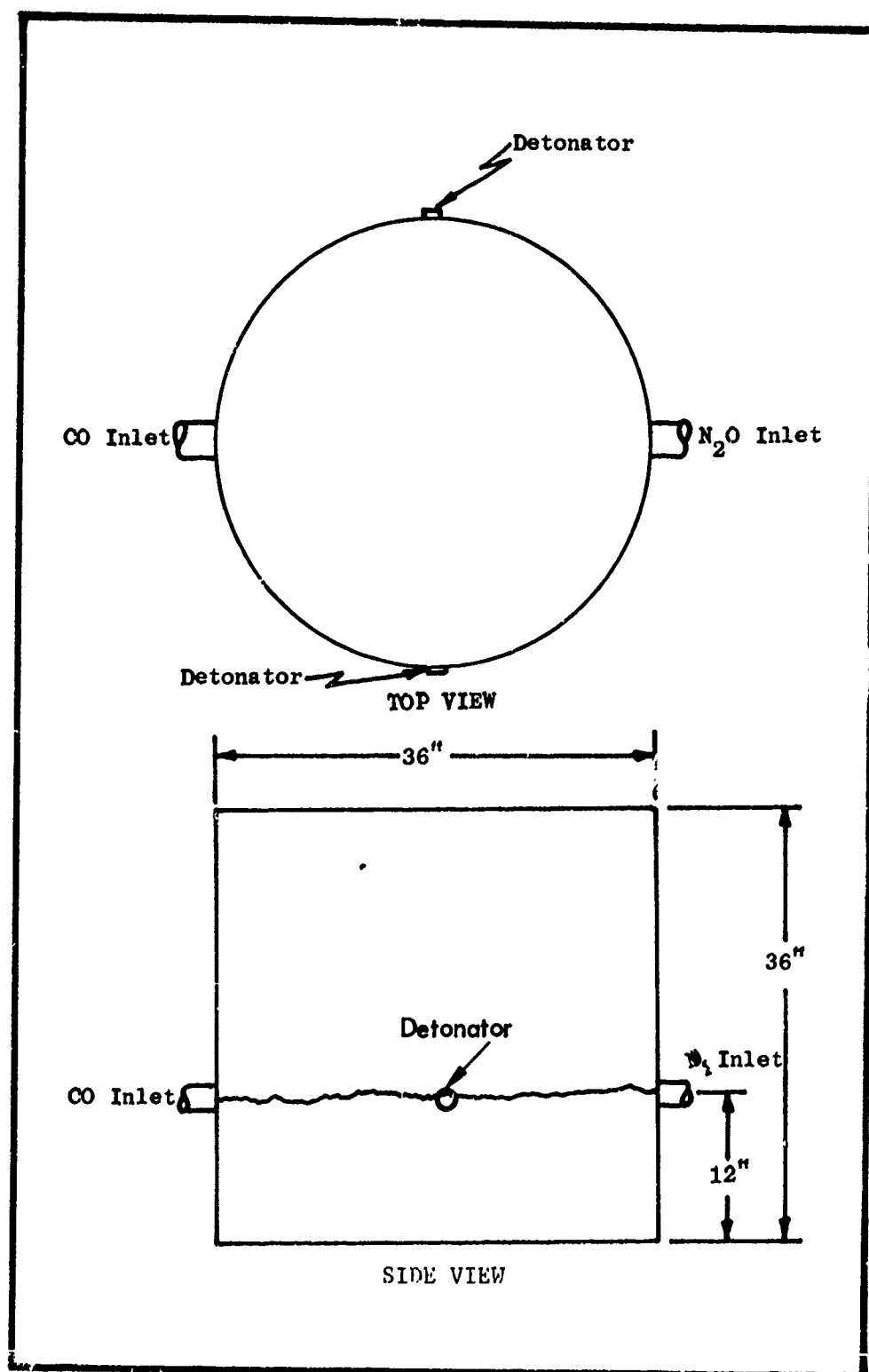
Fig. 1. Sketch of Test Configuration for Semi-Confined Tests

Table I

SUMMARY OF SEMI-CONFINED TESTS

	Test 4	Test 5	Test 6	Test 28 (Aug. 29)	Test 24 (Aug. 29)	Test 25 (Approx. Aug. 31)
Confinement[1]	tank	tank	tank	tank	tank	tank
Weight CO (lbs)	180	180	180	180	180	180
Weight N_2O (lbs)	270	270	270	270	270	-
State:	liquid	liquid	liquid	liquid	liquid	-
Diam[2] (in.)	1-1/2	1-1/2	1-1/2	1-1/2	1-1/2	1-1/2
Separation[2] (ft)	3	3	3	3	3	3
Time Lag[3] (sec)	3	0	0	0	3	-
CO Fueling Time (sec)	25	25	25	25?	25?	25
N_2O Fueling Time (sec)	25	25	25	25?	25?	-
Ignition Source[4]	2 caps	2 caps	2 caps	1 cap 1 squib	1 cap 1 squib	1 cap 1 squib
Ignition Delay[5]	2	2	2	2	2	2

(1) Cylindrical tank 3 feet in diameter, 3 feet high
(2) Diameter of fill lines - separation of fill lines
(3) Between end of CO and start of N_2O filling (Q) denotes simultaneous filling.
(4) Height of caps 12 inches, height of quiescent liquid 12 inches; caps and squib at side of tank
(5) Time between end of fueling and actuation of initiators

4-3

INSTRUMENTATION SYSTEM

The results of the tests were monitored with blast gauges, cameras, and a limited amount of thermal instrumentation. The blast gauge system consisted of 10 Kistler piezoelectric transducers distributed along two radial lines from ground zero as shown in Fig. 2.[*] Three types of sensor mounts were used; Type A at 7.5-ft, Type B at 13.5, 25 and 40-ft and Type C at 70 and 140-ft. Sketches of Types B and C mounts are shown in Fig. 3 and photographs of all three types are presented in Fig. 4. To insure its correct operation the blast instrumentation system was periodically calibrated during the test program with high explosive charges of known characteristics. The results of the high explosive calibration tests are given in Appendix A.

The basic photographic system consisted of two high speed cameras operating at speeds of 1000 frames/sec and one normal speed camera operating at 24 frames/sec. The location of the cameras is shown in Fig. 5.

TEST RESULTS AND CONCLUSIONS

The results obtained from the six tests utilizing the semi-confined condition are summarized in Table 2 along with the particular test conditions which were varied from test to test. The peak overpressure and positive phase impulse data from which the explosive yield values were obtained for the two tests which resulted in explosions are given in Table 3.

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[*] It should be noted that the type of blast instrumentation system used is similar to, but less extensive than, that used in the Project PYRO Program and the reader is referred to Ref. 1 for a detailed description of the system
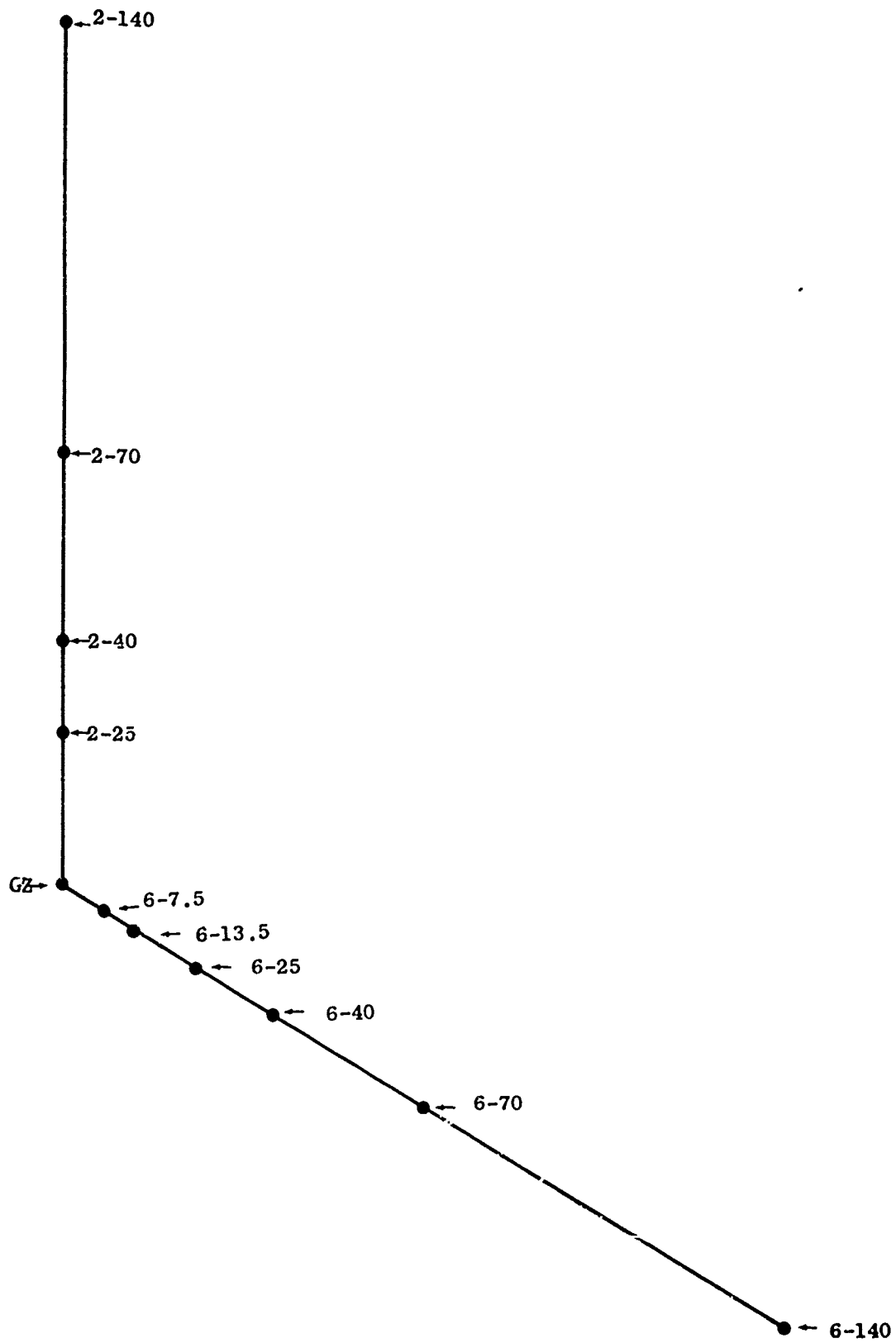
Fig. 2. Instrumentation Layout 4-5

Side-on Overpressure Gauge

Type B Sensor Mount

12 in.

Side-on Overpressure Gauge
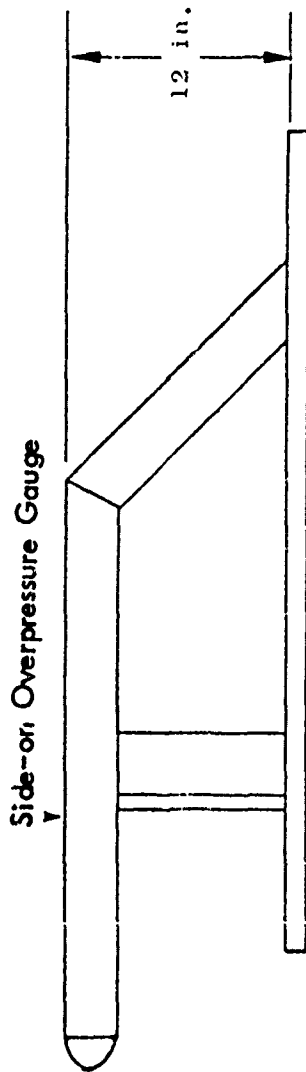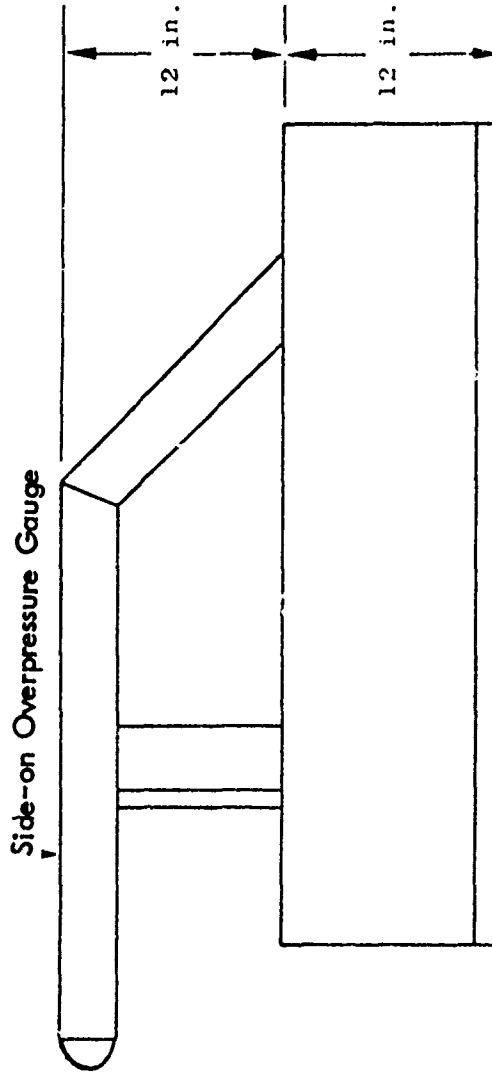
Type C Sensor Mounts

12 in.

12 in.

Fig. 3. Sensor Mounts (Type B and C)

4-6
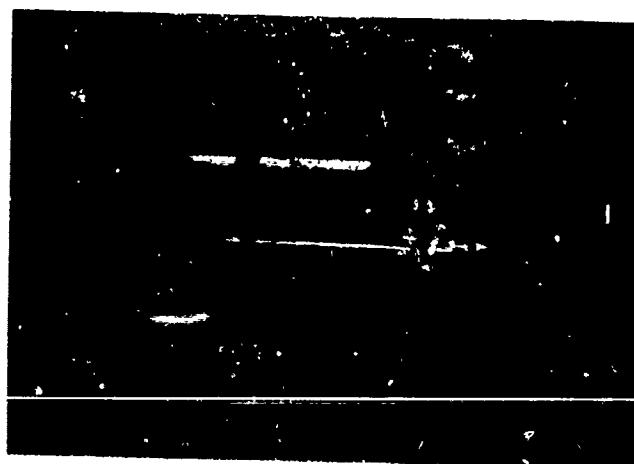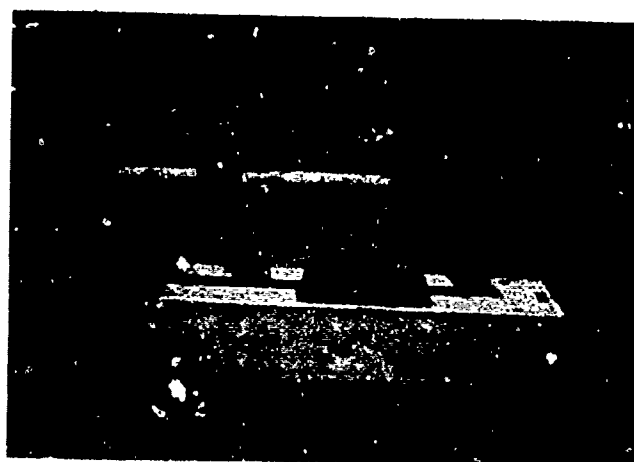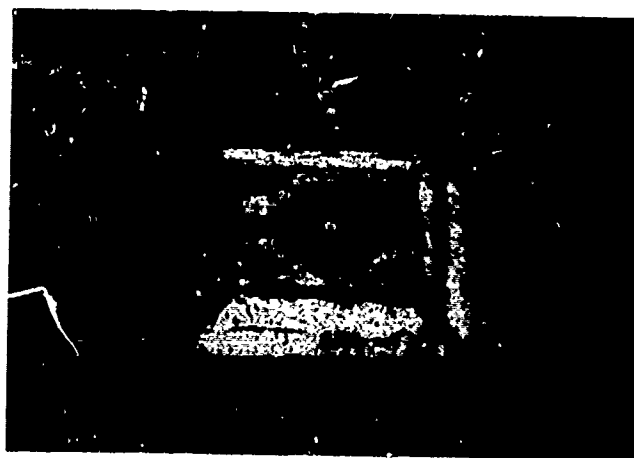
Fig. 4. Photographs of Sensor Mounts

Camera 3

~ Instrumentation
Leg 2

300'

G2

Instrumentation Leg 6

300'

Camera 2

Camera 1

Documentary – on Block
House~1000 ft
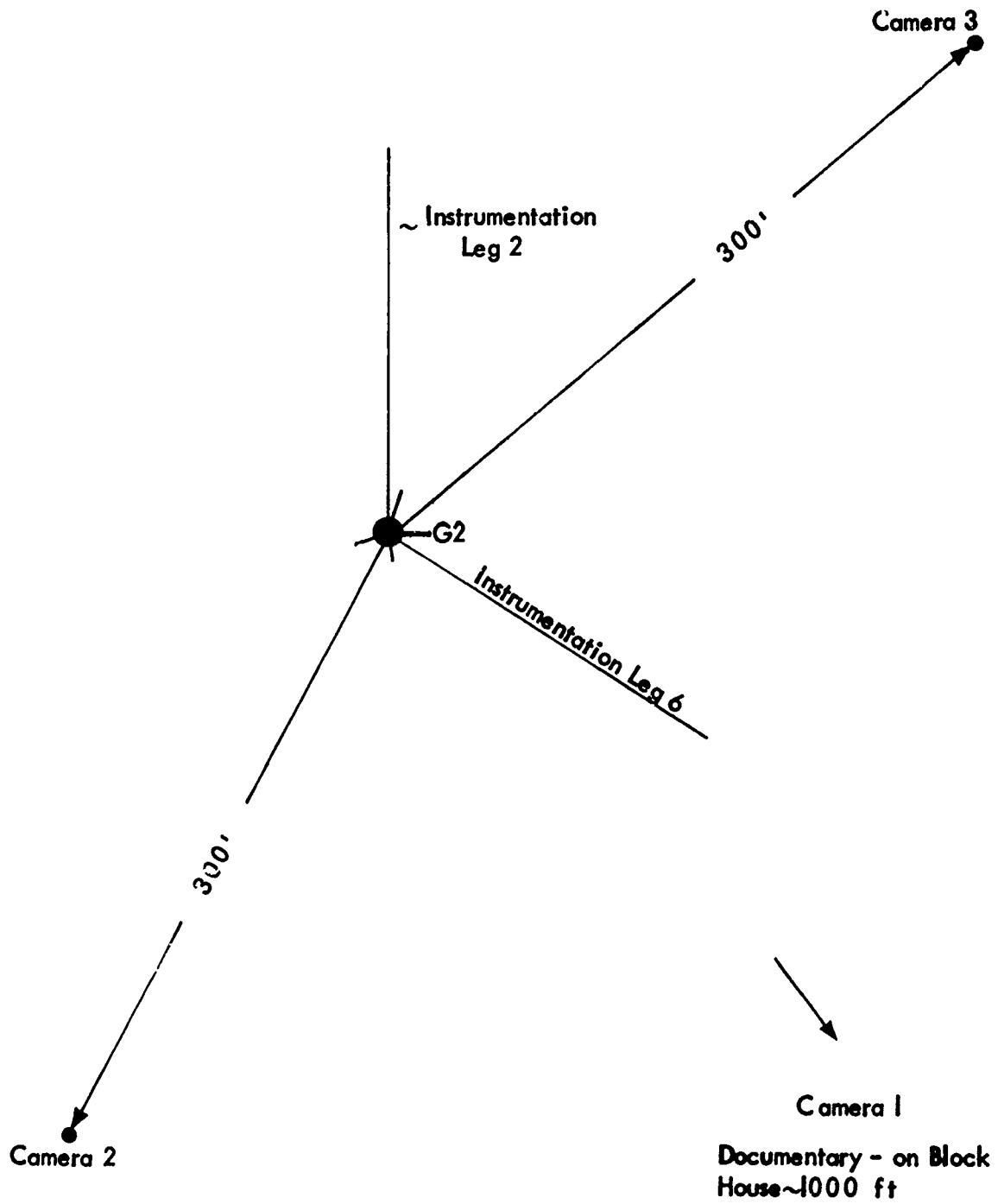
Fig. 5. Layout of Camera Locations

One of the most striking features of these results is that explosions were only obtained on two of the five tests in which both propellants were used. (The lack of an explosion on Test No. 25 is not unexpected since only LCO was used.) This lack of explosion was a surprising result in light of the ease of ignition of previously studied liquid propellants. It had been found for both $LO_2/RP1$ and LO_2/LH_2 that virtually any type of ignition source, either flame or shock, was sufficient to ignite the mixture, that a flame ignition would lead to an explosion, and that the explosive yield was essentially independent of the nature of the ignition.[*]

From Table 2 it can be seen that there is very little correlation between explosive yield and test conditions. In one test out of two (Test No. 4) in which both propellants were released into the test tank sequentially an explosion was obtained (explosive yield 38%). In one test out of three (Test No. 6) in which the propellants were released simultaneously an explosion was obtained (explosive yield 16%).[**] In the one test in which only LCO was used no explosion was obtained. Perhaps the best correlation obtained was with the nature of the initiating source. In two of the three tests in which two detonators were used explosions were obtained while in neither of the two tests in which one detonator and one squib were used was there any explosion. The latter comparison does not include the test with only LCO.

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[*] Unfortunately the full extent of the insensitivity to ignition was not discovered until near the end of the program. The semi-confined tests were run in two series of three each; one at the start of the program, and the other at the end of the program. (The separation was primarily due to the reorientation to gas phase tests mentioned previously.) On the very first propellant test (No. 4) a large explosion was obtained. On the second test (No. 5) no fire or explosion was obtained although both detonators were found to have been fired and the timing and firing circuits all appeared to be operating correctly. On the third test (No. 6) again an explosion was obtained although smaller than on Test No. 4. At this stage it was suspected that something had gone wrong with the experimental arrangement on Test No. 5 since not even a fire was obtained. However, because of this problem it was decided in the later tests to substitute a squib (flame source) for one of the two caps. Since the effects of the squib extend over a much larger area than that of a detonator, it was much more likely to at least lead to flame ignition.

[**] The digitized data for these two tests (4 and 6) is presented in Appendix C.

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Table 2

SUMMARY OF RESULTS FROM SEMI-CONFINED TESTS

Test Conditions	Test No.					
	4	5	6	23	24	25
Both Propellants	yes	yes	yes	yes	yes	LCO only
Fill Method[1]	seq.	sim.	sim.	sim.	seq.	----
Ignition Source	2 caps	2 caps	2 caps	1 cap 1 squib	1 cap 1 squib	1 cap 1 squib
Results						
Fire	yes	no	yes	yes	yes	yes
Explosion	yes	no	yes	no	no	no
Terminal Yield	38%	0	16%	0	0	0

1. Seq. = sequential, sim. = simultaneous

Table 3

PEAK OVERPRESSURE, POSITIVE PHASE IMPULSE
AND
EXPLOSIVE YIELD RESULTS FROM SEMI-CONFINED TESTS

		TEST 4		
Gauge Location	Peak Incident Overpressure (psi)	Pressure Yield (%)	Impulse (psi/msec)	Impulse Yield (%)
Azimuth/Dist. (ft)				
2-25	89.9	78.9	90.2	45.2
2-70	7.0	43.0	34.2	37.2
2-140	2.1	33.9	17.1	37.9
6-7.5	476	22.1	76.5	7.32
6-13.5	100	14.2	52.0	8.11
6-25	73.4	61.3	91.0	46.7
6-40	20.2	42.5	56.3	38.1
6-70	6.8	41.0	30.7	31.3

Estimated Torminal Yield 38%

		TEST 6		
2-25	32.4	20.9	36.2	9.91
2-40	9.7	13.6	28.1	12.1
2-70	3.0	15.0	18.0	14.1
2-140	1.5	15.8	10.4	18.2
6-7.5	66.0	1.46	25.7	1.15
6-13	52.1	5.65	37.5	4.79
6-25	24.7	14.0	62.0	24.4
6-40	8.6	11.6	38.3	20.0
6-70	3.6	12.9	19.2	15.5

Estimated Terminal Yield 16%

NOTE: The individual explosive yield numbers associated with each peak overpressure and posi-
tive phase impulse value and the terminal yield number for each test were calculated as
described in Appendix A, Volume 3 of Reference 1. The terminal yield is the yield ob-
tained at long distances from the explosion where both the pressure and impulse yields
tend to reach a constant value.

One other interesting feature of the results is that in neither test with both propellants in which flame ignition occurred did an explosion occur. (Flame ignition from the detonators might have occurred prior to explosions, however, if it did, the sequence was too fast to detect with the high speed cameras.)

The results from the six tests suggest the following tentative conclusions regarding ignition behavior:

1. Two detonators are sufficient to initiate an explosion, however, one or both must be in close contact with a particular mixture of the propellants

2. It may not be possible to get an explosion from flame ignition.

3. The explosive yield of the propellant combination may well be a function of the strength and location of the initiator in relation to the propellant mixture.

Because of the limited data it is very difficult to conclude anything definite regarding the maximum explosive yield obtainable for the semi-confined test condition. In one test out of five using both propellants a yield of 38%, or on the order of one-half the theoretical maximum, was obtained. It does seem unlikely that an even larger yield could be achieved in another series of five tests using the same ignition sources. And, if an even stronger ignition source is used, the likelihood of getting a larger yield is even greater.

In applying the above information to the situation of concern it should be pointed out that the semi-confined test condition with vertical walls was expected to give higher explosive yields than would occur with any actual failure. All the propellants were released into a tank that only permitted evaporative losses up to the time of ignition and these losses were accounted for in computing explosive yield. In other words, only the quantity of propellants in the tank at the time of ignition were used in computing explosive yield.

In any actual failure, similar propellant behavior is quite unlikely. (The case was selected for testing because if the hazard could be shown to be small it would be unecessary to investigate an entire range of other less potentially hazardous conditicns.)

Keeping in mind the consorvative nature of the test conditions, if it can be shown that potential ignition sources in the vicinity of the failure are no stronger or better distributed than the detonator caps used in the tests, it does not seem unreasonable to select the value of 38% obtained from the largest explosion as an interim explosive yield number for the proposed test facility.

It is clearly desirable, however, to conduct additional tests to clarify the suspected dependence of yield on initiator characteristics and to investigate the semi-confined case without vertical confinement.

Section 5
UNCONFINED TESTS

These tests were intended to investigate the interaction of propel-
lants in the absence of any confining surfaces such as the ground surface
which would tend to enhance early mixing of the propellants in the liquid
phase.

TEST CONDITIONS

In these tests, propellants in the liquid phase were fed through lines
into nozzles which sprayed the liquid into ambient air. To minimize the
effects of variations in air conditions, the nozzles were placed in adja-
cent corners of a 12-ft long by 12-ft wide by 8-ft high enclosure consist-
ing of nylon parachute material draped over a metal frame. The nozzles
were mounted horizontally at a height of 12 in. above the ground and ori-
ented to spray diagonally across the tent. Although the enclosure clearly
provides some degree of confinement for gases at ambient pressure it in
no way tended to force the two liquid sprays to mix with each other, so
it was deemed to satisfy the basic requirements of the test condition.
The number of nozzles used for each propellant varied from one to four
in the various tests. A sketch of the test configuration is shown in
Fig. 6, and pictured in Fig. 7. Two initiators were used in each test,
a det a tor and a squib. A summary of the conditions for each test is
given in Table 4.

TEST RESULTS AND CONCLUSIONS

As can be seen from Table 4 a total of four tests were run for this
condition: three with both propellants, and one with LCO only. In all
cases a fire was obtained, but in no case was an explosion obtained. The
lack of any explosions is not surprising in light of the results of the
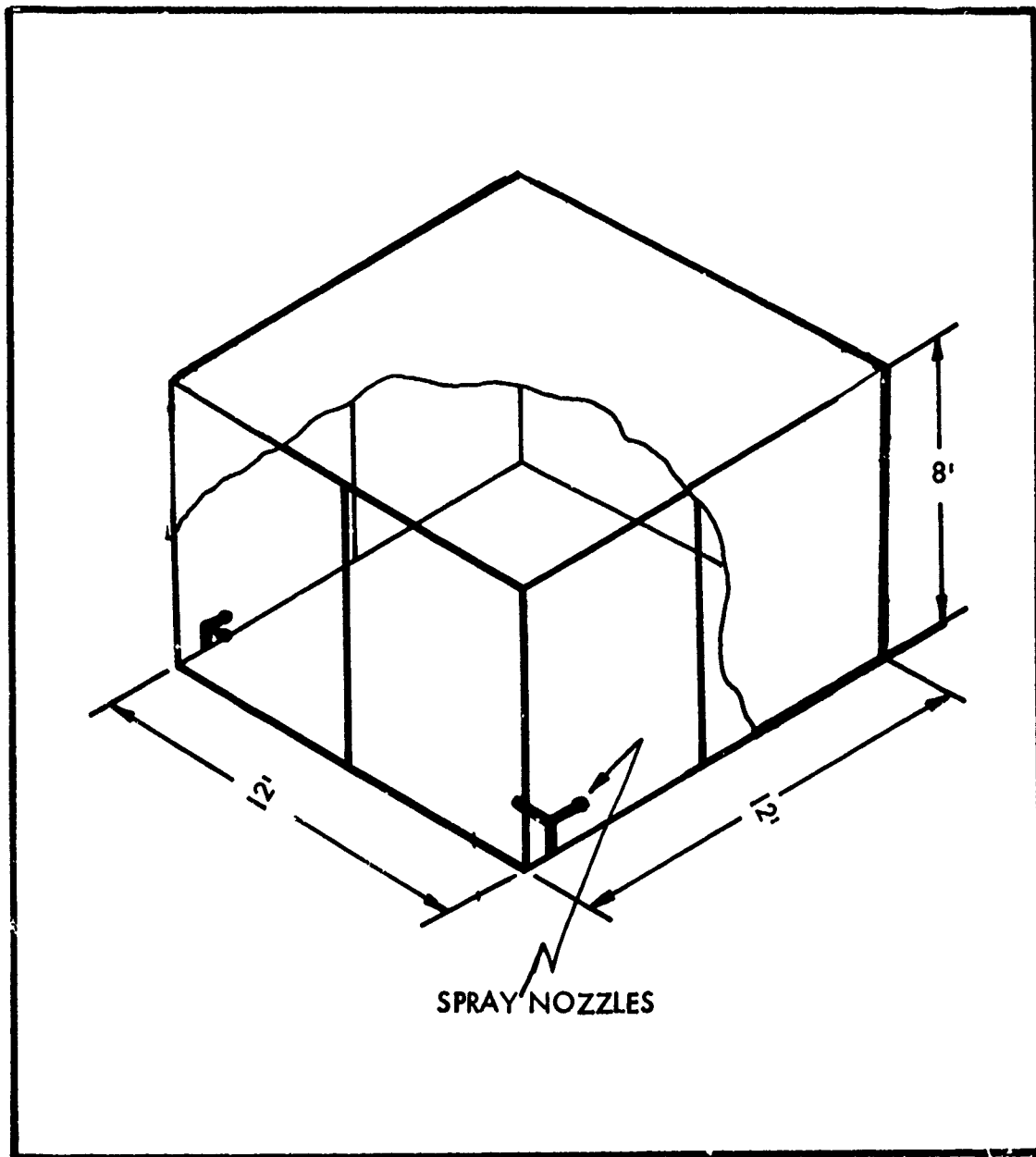
Fig. 6. Sketch of Configuration Used for Unconfined Tests
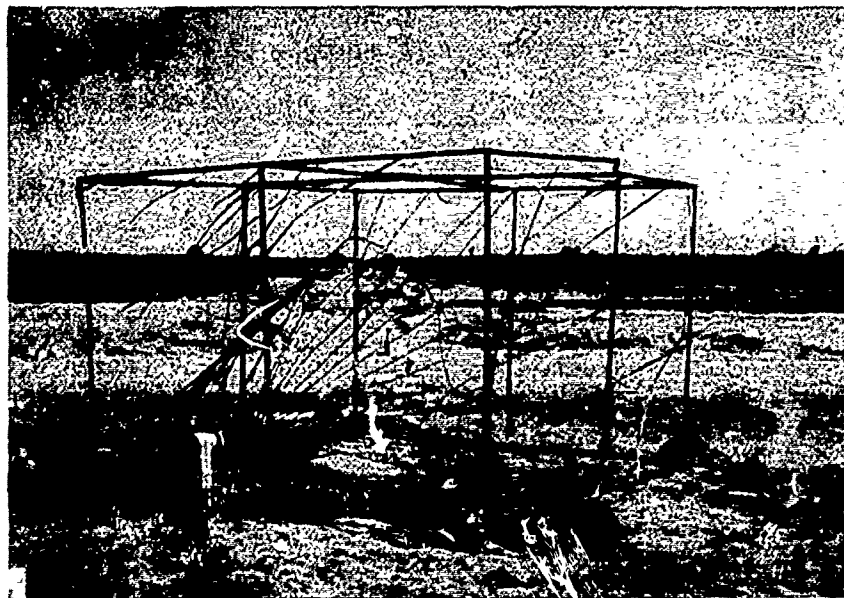
Fig. 7. Pre and Posttest Photos - Unconfined Test Number 16

Table 4

SUMMARY OF TEST CONDITIONS
FOR
UNCONFINED TESTS

	Test Number			
	16	17	18	19
Weight LCO (lbs)	110	334	334	334
Weight LN_2O (lbs)	0	321	321	485
State	liquid	liquid [3]	liquid [3]	liquid
No. of nozzles	2	2	2	4
Separation (ft) [1]	-	12	12	12
Time lag [2]	-	sim	sim	sim
LCO fuel time (sec)	60	40	40	40
LN_2O fuel time (sec)	-	40	40	40
Ignition source	1 cap 1 squib	1 cap 1 squib	1 cap 1 squib	1 cap 1 squib
Ignition delay (sec)	2	2	2	2

(1) Separation of nozzles

(2) Sim means both propellants released simultaneously

(3) Posttest inspection indicated a sizeable quantity of frozen N_2O (like snow) remaining on the ground after those tests.

semi-confined tests in which even though the detonators and squibs were right at the surface of the mixed pool of propellants, explosions were only obtained in two cases out of five (or six if the LCO only case is included). In the present case, the sprayed liquids were distributed throughout a large volume and the probability of the initiation sources being close enough to the type of mixture which could explode (if such a mixture exists for this type of mixing) is certainly far less than it is with the semi-confined case. The fact that the fires did not lead to explosions is also consistent with the semi-confined test results.

Basically, these tests confirm what was initially anticipated: that the unconfined case is a less hazardous condition than the confined case. Although the results further suggest the possibility that the unconfined case has no significant explosive hazard, they are really far too limited to make this a very firm conclusion particularly if stronger or better distributed initiating source are used. Although further studies of the effect of initiators in the unconfined case would be interesting, it seems clear that the semi-confined case will be the limiting hazard for the present application and thus that studies of the unconfined case are not warranted at present.

Section 6
GAS PHASE TESTS

As discussed earlier the original program did not include any tests in which the propellants would be in the gas phase prior to their release and subsequent mixing because the hazard from this condition was considered to be inherently much less than that from liquid phase mixtures. When, however, due to changes in the conceptual design of the basic system, it appeared that liquid mixing was not credible, gas phase tests were added to the program since that was the only remaining credible explosive hazard.

TEST CONDITIONS

To eliminate the effects of ambient air conditions, as in the unconfined liquid phase tests, the gaseous propellants were also confined in a very light-weight non-rigid enclosure. For those tests, the enclosure consisted of a one mil thick meteorological balloon. The propellants were loaded slowly into the balloon sequentially through a single 1/4 in. diameter pipe. The initiators used for this configuration were detonator caps fastened to a ring that supported the base of the balloon pictured in Fig. 8.

Tests were conducted with both CO/air and CO/N_2O mixtures in various weights and mixture ratios. A summary of the test conditions is given in Table 5.

TESTS RESULTS AND CONCLUSIONS

As can be seen from Table 5 a total of five tests were run: three with CO/air and two with CO/N_2O. In none of the five tests was an explosion obtained although fires were obtained on both of the CO/N_2O tests and on one of the three CO/air tests (No. 12).
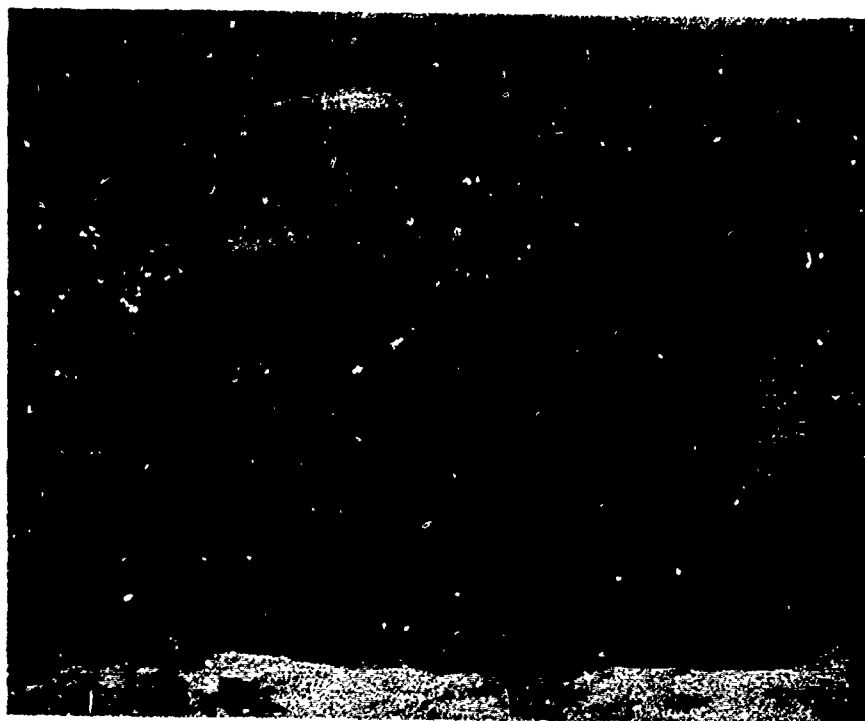
Balloon Inflated
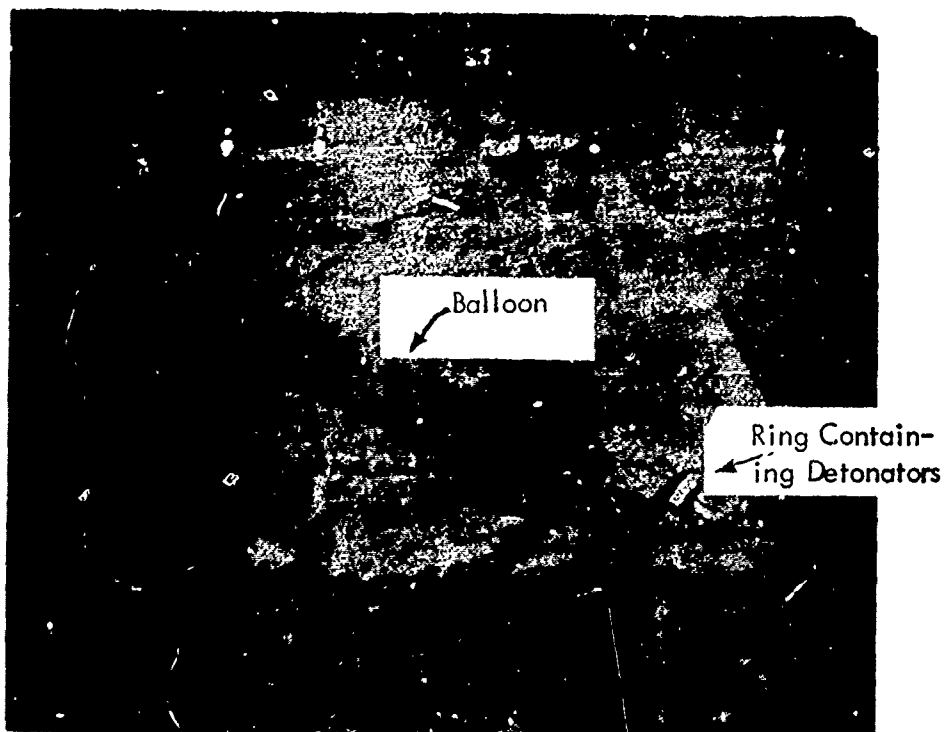
Balloon Prior to Test Showing Hold
Down and Location of Detonation

Fig. 8. Photos of balloon Used in Gas Phase Tests

Table 5

SUMMARY OF TEST CONDITIONS FOR GAS PHASE TESTS

	Test Number				
Test Condition	12	13	14	21	22
Weight CO (lbs)	12.0	19.0	29.4	19.5	19.5
Weight O_2 (lbs	8.3	10.9	8.3	-	-
Weight N_2O (lbs)	-	-	-	31.0	31.0
Weight N_2 (lbs)	22.6	46.4	28.0	-	-
CO/O_2 Ratio	1.65/1	2/1	3.9/1	-	-
CO/N_2O Ratio	-	-	-		
Ignition Source	2 caps	2 caps	2 caps	2 caps	2 caps
Ignition Delay (sec)	30	30	30	30	30

Notes:

1. All gases at ambient temperature

2. One additional test was conducted (No. 11), however, the balloon burst before the firing sequence was actuated and the detonators were not fired.

Essentially the same types of tentative conclusions can be drawn from these tests as were drawn from the unconfined liquid phase tests, i.e., the gas phase condition is less hazardous than the semi-confined liquid phase case. Again, it cannot be concluded that an explosion would not have occurred with stronger and better located ignition sources. However, as long as the semi-confined liquid phase case is credible, it represents the limiting hazard and further study of the gas phase case is not warranted at present.

Section 7

SUMMARY OF CONCLUSIONS
AND
RECOMMENDATIONS

Because of the limited nature of the test program, and the wide variability in results for some conditions, the conclusions that have been drawn from the results need rather careful qualification. It was thought that this could best be done by including the conclusions with the discussion of results. Here, only a summary of the significant conclusions is given and the reader is cautioned to review the three Test Results Sections very carefully before applying these conclusions to ensure that they are not being misused.

CONCLUSIONS

1. Liquid phase mixtures of the propellant combination LCO/LN_2 represent a significant explosive hazard.

2. It is more difficult to initiate an explosion for this propellant combination than for $LO_2/RP1$ or LO_2/LH_2.

3. Two detonators are able to initiate an explosion but do not guarantee it.

4. It does not seem likely that explosions can be initiated with flame sources.

5. The explosive yield of this propellant combination is likely to be a function of the strength and location of the initiating source relative to the propellant mixture.

6. Higher explosive yields are expected for mixing of liquid phase propellants in the presence of confining surfaces than for spills of liquid or gas phase propellants in free air.

RECOMMENDATIONS

1. An interim explosive yield value of 38% should be used for hazards evaluation of the proposed facility, providing it can be shown that the potential ignition sources are not stronger or better distributed than the two detonators used in the test program.

2. Further tests should be conducted to investigate the effect of ignition characteristics on explosive yield for propellant spills in the vicinity of confining surfaces. This condition is of importance because it represents the worst credible explosive hazard for the propellant combination. As such the yield value obtained from it could be considered an upper limit for any use of the propellant combination, and thus can be used for the test facility independent of its specific design. The limited data obtained for this condition to date indicates the liklihood that the yield is dependent on the strength and distribution of the ignition source. Further tests are needed to evaluate the overall nature of this suspected dependence. Until it is better understood the explosive yield value for this condition cannot be specified with any degree of certainty. Specifically recommended tests are outlined in detail in Appendix B.

3. Some tests should be conducted of the semi-confined case without vertical confining walls to test the expected result that explosive yields are lower than with confining walls, as has been found with other propellant combinations.* With proper design it may be possible in the proposed test facility to eliminate the possibility of any pooling of propellants and thus the worst credible hazard would result from spills on a flat ground surface. Specifically recommended tests are outlined in Appendix B.

4. An analysis should be performed of potential ignition sources in the proposed test facility. If it can be shown that the maximum credible ignition sources are weaker and/or more poorly distributed than those needed to make the propellant mixture give its full yield potential, lower credible yields can be justified for the particular application.

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* This case was included in the original test program but was eliminated because of reorientation of effort.

REFERENCES

1. Willoughby, A. B., C. Wilton, and J. Mansfield, Liquid Propellant
   Explosive Hazards, URS 652, Final Report, December 1968 (three vol-
   umes), URS Research Company, Burlingame, California.

Appendix A

DIGITIZED DATA FOR TEST 9
32 lb HIGH-EXPLOSIVE CALIBRATION TEST

Appendix A
HIGH EXPLOSIVE CALIBRATION TESTS

Calibration of the blast instrumentation system was performed throughout the program by detonating spherical charges of high explosives whose explosive properties are well known (Composition C-4 and Pentolite). The purpose of these tests was to verify the correct overall operation of the blast instrumentation system, both initially and throughout the program.

In all cases the charges were spherical and were detonated at a scaled height of burst (HOB) of about $1\text{-ft/lb}^{1/3}$. This charge height was selected because it was high enough to minimize damage to the test pad and still low enough to ensure a well-developed shock front at the closest above-surface transducer. Furthermore, this charge height is high enough so that the particular nature of the ground surface would not significantly influence the results.

During the test program a total of six calibration tests were conducted: three using 20 lb C-4 charges; and three using 32 lb pentolite charges.

The data for these calibration tests (as well as the propellant tests) are obtained for AFRPL in the form of hard copy oscillograph records. These records are placed on the URS Data Recorder and digitized. Data reduction and processing are accomplished in a XDS 940 computer. The output of the computer programs is in the form of tables of average pressure and impulse at 0.1 msec intervals. For reference purposes the computer output for two of the 32 lb calibration tests (Test 9 and 10) are included at the end of this Appendix.

The peak overpressure data from theses are plotted in Fig. A-1,[*] a graph of peak pressure vs scaled distance, and the positive phase impulse data are plotted in Fig. A-2,[**] a graph of scaled positive phase impulse vs scaled distance.

The surface burst reference curves included with the calibration data plots are based on TNT surface burst data given in Refs. A1 and A2 for pressure and impulse respectively. For use in these plots these reference curves have been adjusted to pentolite base. This adjustment uses 1.18 lb of TNT as equivalent to 1 lb of pentolite.

Also included are reference curves based on spherical charges of Composition A detonated at a scaled HOB of 1.4-ft/lb$^{1/3}$ (from Ref. A-3).[***] As would be expected the surface burst data tend to lie somewhat below the calibration data collected at a scaled HOB of 1.0-ft/lb$^{1/3}$ and closer to the Composition A data collected at a scaled HOB of 1.4-ft/lb$^{1/3}$.

[*] Kingery, C. N. and B. F. Pannill, Peak Overpressure vs. Scaled Distance for TNT Surface Bursts (Hemispherical Charges), BRL Memorandum Report No. 1518, Ballistic Research Laboratories, April 1964 (AD 443 102).

[**] Defense Atomic Support Agency, Operation SNOW BALL Project Descriptions, Volume 1 (U), DASA Data Center Special Report 24-1, DASA 1516-1 (AD 441 974).

[***] Wilton, C, K. Kaplan, and N. Wallace, Study of Channeling of Air Blast Waves, Final Report, URS 170-19, DASA-1605, URS Corporation for the Defense Atomic Support Agency, Burlingame, California, December 1964.
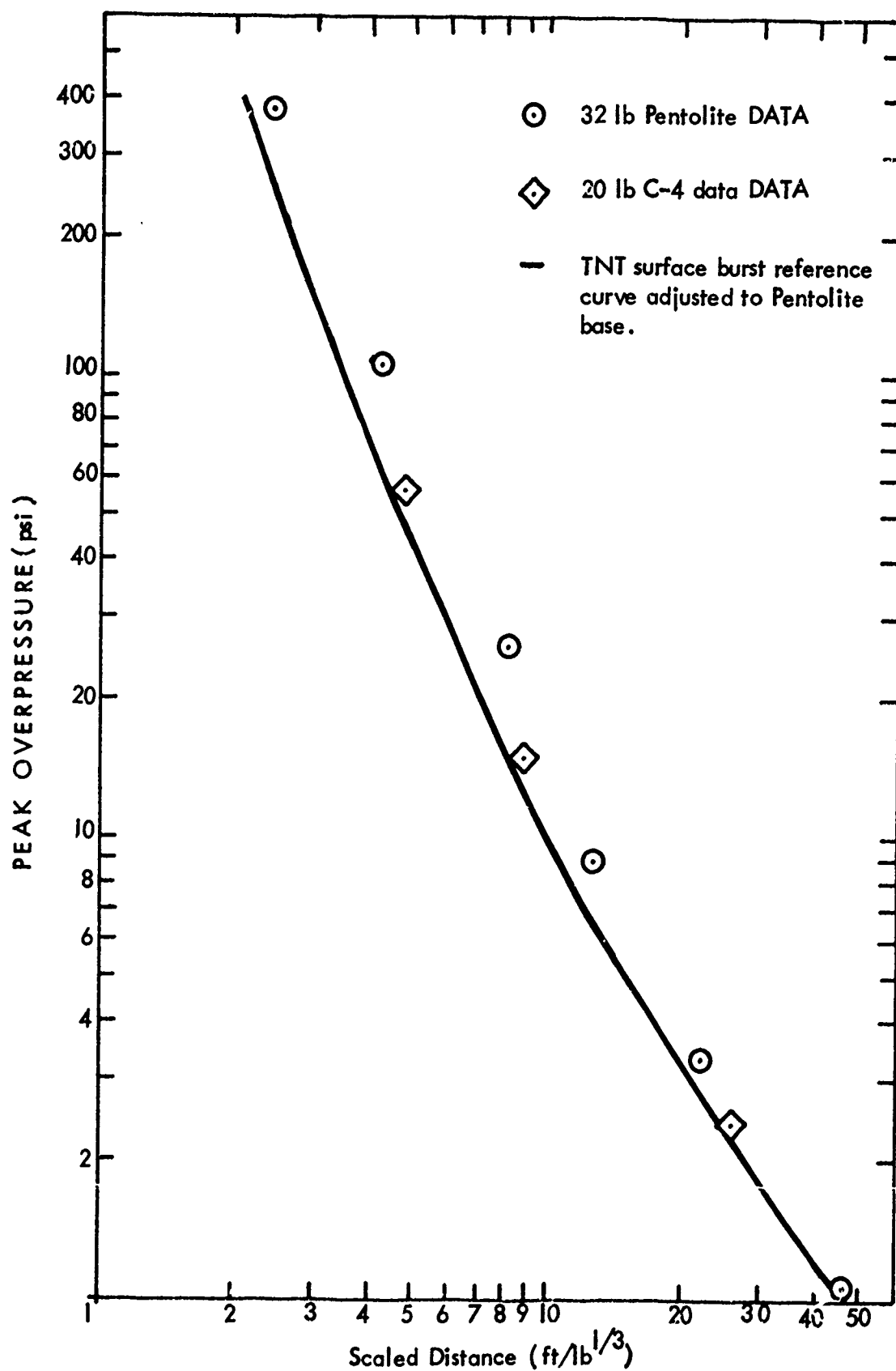
Fig. A-1. Peak Overpressure Data, Tests 9 and 10
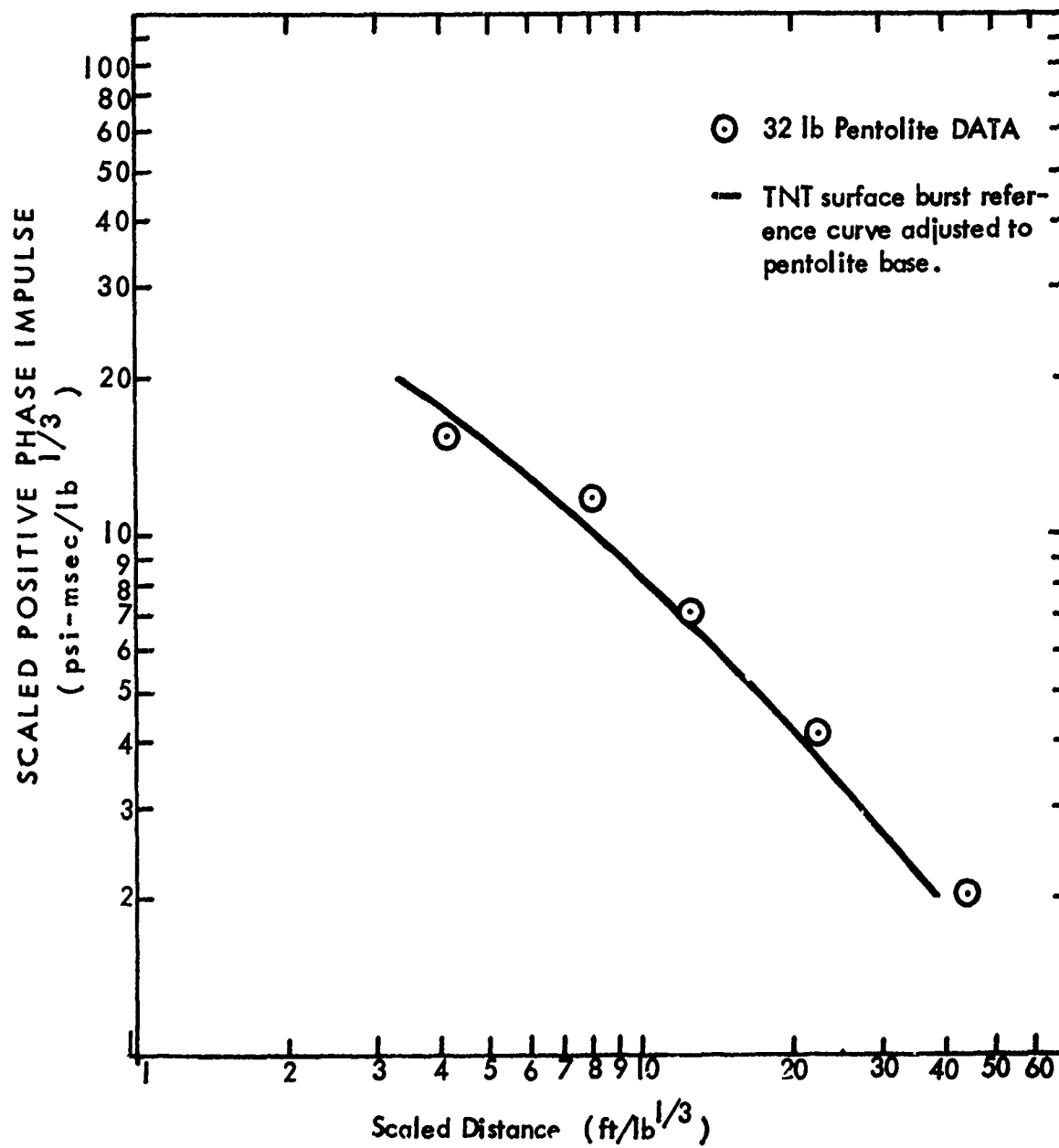
Fig. A-2. Positive Phase Impulse Data, Tests 9 and 10.

TEST 9

32 POUND HE CALIBRATION
6 O'CLOCK LEG, 13 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	113	0
.1	61.5	8.725
.2	34.533	13.526
.3	18.766	16.191
.4	22.1	18.235
.5	25.433	20.611
.6	28.766	23.321
.7	32.1	26.365
.8	28.905	29.415
.9	25.711	32.146
1	22.516	34.557
1.1	17.727	36.569
1.2	17.818	38.346
1.3	19.425	40.209
1.4	16.917	42.026
1.5	13.004	43.522
1.6	9.091	44.627
1.7	7.55	45.459
1.8	6.272	46.15
1.9	4.994	46.713
2	3.716	47.149
2.1	2.438	47.456
2.2	1.721	47.664
2.3	1.563	47.829
2.4	1.405	47.977
2.5	1.247	48.11
2.6	1.352	48.24
2.7	1.569	48.386
2.8	1.786	48.554
2.9	2.004	48.743
3	2.1	48.948
3.1	1.1	49.108
3.2	1E-01	49.168

TEST 9

32 POUND HE CALIBRATION
6 O'CLOCK LEG, 25 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	26.3	0
.1	19.7	2.3
.2	16.344	4.102
.3	17.7	5.804
.4	15.342	7.456
.5	13.733	8.91
.6	15.214	10.357
.7	13.357	11.786
.8	13.436	13.126
.9	12.42	14.418
1	11.316	15.605
1.1	11.009	16.721
1.2	10.703	1⁻807
1.3	10.397	18.862
1.4	10.09	19.887
1.5	9.784	20.88
1.6	9.478	21.843
1.7	9.171	22.776
1.8	9.36	23.703
1.9	8.7	24.606
2	7.922	25.437
2.1	7.144	26.19
2.2	6.514	26.873
2.3	6.229	27.51
2.4	5.943	28.119
2.5	5.658	28.699
2.6	5.373	29.251
2.7	5.088	29.774
2.8	4.802	30.268
2.9	4.517	30.734

3	4.232	31.172
3.1	3.947	31.581
3.2	3.661	31.961
3.3	3.376	32.313
3.4	3.223	32.643
3.5	3.278	32.968
3.6	3.088	33.286
3.7	2.898	33.586
3.8	2.708	33.866
3.9	2.518	34.127
4	2.328	34.37
4.1	2.138	34.593
4.2	1.948	34.798
4.3	1.758	34.983
4.4	1.568	35.149
4.5	1.378	35.297
4.6	1.672	35.449
4.7	1.527	35.609
4.8	1.381	35.755
4.9	1.236	35.886
5	1.09	36.002
5.1	.945	36.104
5.2	.8	36.191
5.3	.654	36.264
5.4	.509	36.322
5.5	.363	36.366
5.6	.218	36.395
5.7	.072	36.409

TEST 9

32 POUND HE CALIBRATION
6 O'CLOCK LEG, 40 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	9.78	0
.1	8.543	.916
.2	7.307	1.708
.3	7.873	2.467
.4	7.62	3.242
.5	7.423	3.994
.6	7.227	4.72′
.7	7.03	5.44
.8	6.834	6.133
.9	6.637	6.806
1	6.441	7.46
1.1	6.245	8.095
1.2	6.048	8.709
1.3	5.852	9.304
1.4	5.655	9.88
1.5	5.459	10.436
1.6	5.263	10.972
1.7	5.066	11.488
1.8	4.944	11.989
1.9	5.246	12.498
2	4.846	13.003
2.1	4.264	13.459
2.2	4.176	13.881
2.3	4.088	14.294
2.4	4	14.698
2.5	3.912	15.094
2.6	3.825	15.481
2.7	3.737	15.859
2.8	3.649	16.228
2.9	3.561	16.589

3	3.473	16.941
3.1	3.385	17.284
3.2	4.43	17.674
3.3	3.35	18.063
3.4	3.095	18.386
3.5	3.156	18.698
3.6	1.99	18.955
3.7	2.851	19.198
3.8	2.328	19.457
3.9	2.345	19.69
4	2.87	19.951
4.1	1.939	20.191
4.2	2.26	20.401
4.3	2.284	20.629
4.4	1.472	20.817
4.5	2.153	20.998
4.6	2.346	21.223
4.7	1.68	21.424
4.8	2.251	21.621
4.9	1.27	21.797
5	2.034	21.962
5.1	2.338	22.181
5.2	1.709	22.383
5.3	1.656	22.551
5.4	1.603	22.714
5.5	1.551	22.872
5.6	1.498	23.025
5.7	1.445	23.172
5.8	1.392	23.314
5.9	1.34	23.45
6	1.287	23.582
6.1	1.234	23.708
6.2	1.181	23.829
6.3	1.129	23.944
6.4	1.076	24.055
6.5	1.023	24.16
6.6	.97	24.259
6.7	.918	24.354
6.8	.865	24.443
6.9	.812	24.527

7	.759	24.605
7.1	.706	24.679
7.2	.654	24.747
7.3	.601	24.81
7.4	.548	24.867
7.5	.495	24.919
7.6	.443	24.966
7.7	.39	25.008
7.8	.337	25.044
7.9	.284	25.075
8	.232	25.101
8.1	.179	25.122
8.2	.126	25.137
8.3	.073	25.147
8.4	.021	25.152

TEST 9

32 POUND HE CALIBRATION
6 O'CLOCK LEG, 70 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	3.23	0
.1	3.106	.316
.2	2.864	.615
.3	2.546	.885
.4	2.67	1.146
.5	2.642	1.412
.6	2.614	1.675
.7	2.587	1.935
.8	2.559	2.192
.9	2.531	2.447
1	2.503	2.698
1.1	2.475	2.947
1.2	2.448	3.194
1.3	2.42	3.437
1.4	2.392	3.678
1.5	2.364	3.916
1.6	2.336	4.151
1.7	2.308	4.383
1.8	2.281	4.612
1.9	2.253	4.839
2	2.225	5.063
2.1	2.197	5.284
2.2	2.169	5.503
2.3	2.142	5.718
2.4	2.114	5.931
2.5	2.086	6.141
2.6	2.058	6.343
2.7	2.03	6.553
2.8	2.002	6.754
2.9	1.975	6.953

3	1.947	7.149
3.1	1.919	7.343
3.2	1.891	7.533
3.3	1.863	7.721
3.4	1.717	7.9
3.5	1.686	8.07
3.6	1.655	8.238
3.7	1.624	8.402
3.8	1.593	8.563
3.9	1.563	8.72
4	1.532	8.875
4.1	1.501	9.027
4.2	1.47	9.175
4.3	1.439	9.321
4.4	1.408	9.463
4.5	1.377	9.603
4.6	1.346	9.739
4.7	1.315	9.872
4.8	1.284	10.002
4.9	1.253	10.129
5	1.222	10.253
5.1	1.191	10.373
5.2	1.161	10.491
5.3	1.13	10.606
5.4	1.099	10.717
5.5	1.068	10.825
5.6	1.037	10.931
5.7	1.006	11.033
5.8	.975	11.132
5.9	.949	11.228
6	.928	11.322
6.1	.907	11.414
6.2	.886	11.504
6.3	.865	11.591
6.4	.844	11.677
6.5	.822	11.76
6.6	.801	11.841
6.7	.78	11.92
6.8	.759	11.997
6.9	.738	12.072

7	.717	12.145
7.1	.696	12.216
7.2	.675	12.284
7.3	.654	12.351
7.4	.633	12.415
7.5	.612	12.477
7.6	.591	12.538
7.7	.569	12.596
7.8	.548	12.652
7.9	.527	12.705
8	.506	12.757
8.1	.485	12.807
8.2	.464	12.854
8.3	.443	12.9
8.4	.422	12.943
8.5	.401	12.984
8.6	.38	13.023
8.7	.359	13.06
8.8	.338	13.095
8.9	.316	13.128
9	.295	13.158
9.1	.274	13.187
9.2	.253	13.213
9.3	.232	13.238
9.4	.229	13.261
9.5	.252	13.285
9.6	.275	13.311
9.7	.298	13.34
9.8	.283	13.369
9.9	.23	13.395
10	.177	13.415
10.1	.125	13.43
10.2	.072	13.44
10.3	.025	13.445

TEST 9

32 POUND HE CALIBRATION
6 O'CLOCK LEG, 140 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	1.09	0
.1	1.052	.107
.2	1.086	.214
.3	.957	.316
.4	1.08	.418
.5	1.069	.525
.6	1.058	.631
.7	1.047	.737
.8	1.036	.841
.9	1.026	.944
1	1.015	1.046
1.1	1.003	1.147
1.2	.991	1.247
1.3	.979	1.346
1.4	.967	1.443
1.5	.955	1.539
1.6	.942	1.634
1.7	.93	1.728
1.8	.918	1.82
1.9	.906	1.911
2	.894	2.001
2.1	.882	2.09
2.2	.869	2.178
2.3	.857	2.264
2.4	.845	2.349
2.5	.833	2.433
2.6	.821	2.516
2.7	.808	2.597
2.8	.796	2.678
2.9	.784	2.757

3	.772	2.835
3.1	.76	2.911
3.2	.747	2.987
3.3	.735	3.061
3.4	.723	3.134
3.5	.711	3.206
3.6	.699	3.276
3.7	.687	3.345
3.8	.674	3.413
3.9	.662	3.48
4	.65	3.546
4.1	.638	3.61
4.2	.626	3.674
4.3	.613	3.736
4.4	.601	3.796
4.5	.589	3.856
4.6	.577	3.914
4.7	.57	3.972
4.8	.571	4.029
4.9	.573	4.086
5	.574	4.143
5.1	.575	4.201
5.2	.577	4.259
5.3	.578	4.316
5.4	.579	4.374
5.5	.536	4.43
5.6	.481	4.481
5.7	.46	4.523
5.8	.462	4.574
5.9	.463	4.621
6	.465	4.667
6.1	.466	4.714
6.2	.468	4.76
6.3	.469	4.807
6.4	.471	4.854
6.5	.472	4.902
6.6	.474	4.949
6.7	.475	4.997
6.8	.477	5.044
6.9	.478	5.092

7	.472	5.14
7.1	.432	5.185
7.2	.414	5.227
7.3	.407	5.268
7.4	.4	5.309
7.5	.393	5.348
7.6	.386	5.387
7.7	.379	5.426
7.8	.371	5.463
7.9	.364	5.5
8	.357	5.536
8.1	.35	5.571
8.2	.343	5.606
8.3	.336	5.64
8.4	.328	5.673
8.5	.321	5.706
8.6	.314	5.738
8.7	.307	5.769
8.8	.3	5.799
8.9	.292	5.829
9	.285	5.858
9.1	.278	5.886
9.2	.271	5.913
9.3	.264	5.94
9.4	.257	5.966
9.5	.249	5.992
9.6	.242	6.016
9.7	.235	6.04
9.8	.228	6.063
9.9	.221	6.086
10	.213	6.108
10.1	.206	6.129
10.2	.199	6.149
10.3	.192	6.169
10.4	.185	6.187
10.5	.178	6.206
10.6	.17	6.223
10.7	.163	6.24
10.8	.156	6.256
10.9	.149	6.271

11	.142	6.286
11.1	.134	6.299
11.2	.127	6.313
11.3	.12	6.325
11.4	.113	6.337
11.5	.106	6.348
11.6	.099	6.358
11.7	.091	6.368
11.8	.084	6.376
11.9	.077	6.384
12	.07	6.392
12.1	.063	6.399
12.2	.056	6.404
12.3	.048	6.41
12.4	.041	6.414
12.5	.034	6.418
12.6	.027	6.421
12.7	.02	6.424
12.8	.012	6.425
12.9	.005	6.426

TEST 9

32 POUND HE CALIBRATION
2 O'CLOCK LEG, 25 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	26.1	0
.1	22.281	2.419
.2	18.463	4.456
.3	18.007	6.279
.4	16.616	8.011
.5	14.618	9.572
.6	14.857	11.046
.7	13.142	12.446
.8	14.1	13.808
.9	13.1	15.168
1	12.1	16.428
1.1	11.1	17.588
1.2	10.1	18.648
1.3	9.1	19.608
1.4	8.303	20.478
1.5	8.318	21.31
1.6	8.333	22.142
1.7	8.348	22.976
1.8	8.363	23.812
1.9	8.378	24.649
2	8.393	25.488
2.1	6.9	26.252
2.2	6.718	26.933
2.3	7.258	27.632
2.4	6.974	28.344
2.5	6.69	29.027
2.6	6.406	29.682
2.7	6.122	30.308
2.8	5.838	30.906
2.9	5.554	31.476

3	5.27	32.017
3.1	4.986	32.53
3.2	4.702	33.014
3.3	4.418	33.47
3.4	4.134	33.898
3.5	3.85	34.297
3.6	3.566	34.668
3.7	3.282	35.01
3.8	2.998	35.325
3.9	3.137	35.631
4	3.2	35.948
4.1	2.656	36.241
4.2	2.57	36.502
4.3	2.484	36.755
4.4	2.398	36.999
4.5	2.311	37.235
4,6	2.225	37.462
4.7	2.139	37.68
4.8	2.053	37.89
4.9	1.966	38.091
5	1.88	38.283
5.1	1.794	38.467
5.2	1.707	38.642
5 3	1.621	38.808
5.4	1.535	38.966
5.5	1.449	39.115
5.6	1.362	39.256
5.7	1.276	39.388
5.8	1.19	39.511
5.9	1.104	39.626
6	1.017	39.732
6.1	.931	39.83
6.2	.845	39.918
6.3	.759	39.999
6.4	.672	40.07
6.5	.586	40.133
6.6	.5	40.188
6.7	.414	40.233
6.8	.327	40.27
6.9	.241	40.299
7	.155	40.319
7.1	.069	40.33

TEST 9

32 POUND HE CALIBRATION
2 O'CLOCK LEG, 40 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	7.89	0
.1	7.031	.746
.2	6.173	1.406
.3	6.536	2.041
.4	6.886	2.712
.5	5.31	3.322
.6	6.376	3.907
.7	6.26	4.538
.8	5.72	5.137
.9	6.162	5.732
1	5.526	6.316
1.1	5.392	6.862
1.2	5.258	7.395
1.3	5.124	7.914
1.4	4.991	8.42
1.5	4.857	8.912
1.6	4.723	9.391
1.7	4.589	9.857
1.8	4.455	10.308
1.9	4.321	10.748
2	4.188	11.173
2.1	4.054	11.585
2.2	3.92	11.984
2.3	3.786	12.369
2.4	3.652	12.741
2.5	3.518	13.1
2.6	3.384	13.445
2.7	3.251	13.777
2.8	3.117	14.095
2.9	2.983	14.4

3	3.832	14.741
3.1	3.261	15.096
3.2	3.01	15.41
3.3	2.897	15.705
3.4	2.784	15.989
3.5	2.67	16.262
3.6	2.557	16.523
3.7	2.444	16.773
3.8	2.33	17.012
3.9	2.217	17.239
4	2.104	17.455
4.1	1.99	17.66
4.2	1.877	17.854
4.3	1.764	18.036
4.4	1.65	18.206
4.5	1.537	18.366
4.6	1.424	18.514
4.7	1.31	18.651
4.8	1.21	18.777
4.9	1.165	18.895
5	1.119	19.01
5.1	1.073	19.119
5.2	1.028	19.224
5.3	.982	19.325
5.4	.936	19.421
5.5	.891	19.512
5.6	.845	19.599
5.7	.799	19.681
5.8	.753	19.759
5.9	.708	19.832
6	.662	19.901
6.1	.616	19.965
6.2	.571	20.024
6.3	.525	20.079
6.4	.479	20.129
6.5	.434	20.175
6.6	.388	20.216
6.7	.342	20.253
6.8	.297	20.285
6.9	.251	20.312

7	.205	20.335
7.1	.159	20.353
7.2	.111	20.367
7.3	.068	20.376
7.4	.022	20.38

TEST 9

32 POUND HE CALIBRATION
2 O'CLOCK LEG, 70 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	3.37	0
.1	3.124	.324
.2	2.879	.624
.3	2.799	.908
.4	2.762	1.186
.5	2.724	1.461
.6	2.687	1.731
.7	2.649	1.998
.8	2.611	2.261
.9	2.574	2.521
1	2.536	2.776
1.1	2.498	3.028
1.2	2.461	3.276
1.3	2.423	3.52
1.4	2.386	3.761
1.5	2.348	3.997
1.6	2.31	4.23
1.7	2.273	4.46
1.8	2.235	4.685
1.9	2.197	4.907
2	2.16	5.125
2.1	2.122	5.339
2.2	2.085	5.549
2.3	2.047	5.756
2.4	2.009	5.959
2.5	1.972	6.158
2.6	1.934	6.353
2.7	1.897	6.545
2.8	1.859	6.732
2.9	1.821	6.917

3	1.784	7.097
3.1	1.746	7.273
3.2	1.708	7.446
3.3	1.671	7.615
3.4	1.638	7.781
3.5	1.608	7.943
3.6	1.578	8.102
3.7	1.548	8.259
3.8	1.518	8.412
3.9	1.488	8.562
4	1.457	8.71
4.1	1.427	8.854
4.2	1.397	8.995
4.3	1.367	9.134
4.4	1.337	9.269
4.5	1.307	9.401
4.6	1.276	9.53
4.7	1.246	9.656
4.8	1.216	9.78
4.9	1.186	9.9
5	1.156	10.017
5.1	1.126	10.131
5.2	1.096	10.242
5.3	.968	10.345
5.4	.948	10.441
5.5	.928	10.535
5.6	.908	10.627
5.7	.888	10.716
5.8	.868	10.804
5.9	.848	10.89
6	.828	10.974
6.1	.808	11.056
6.2	.788	11.135
6.3	.768	11.213
.4	.748	11.289
6.5	.815	11.367
6.6	.743	11.445
6.7	.67	11.516
6.8	.598	11.579
6.9	.47	11.633

7	.446	11.679
7.1	.423	11.722
7.2	.399	11.763
7.3	.376	11.802
7.4	.374	11.839
7.5	.421	11.879
7.6	.468	11.924
7.7	.516	11.973
7.8	.518	12.025
7.9	.474	12.074
8	.431	12.12
8.1	.387	12.161
8.2	.344	12.197
8.3	.3	12.23
8.4	.257	12.257
8.5	.213	12.281
8.6	.17	12.3
8.7	.126	12.315
8.8	.083	12.325
8.9	.079	12.334
9	.093	12.342
9.1	.106	12.352
9.2	.12	12.364
9.3	.133	12.376
9.4	.147	12.39
9.5	.161	12.406
9.6	.174	12.423
9.7	.188	12.441
9.8	.201	12.46
9.9	.19	12.48
10	.14	12.496
10.1	.09	12.508
10.2	.04	12.514

TEST 9

32 POUND HE CALIBRATION
2 O'CLOCK LEG, 140 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	1.03	0
.1	1.024	.102
.2	1.019	.204
.3	1.013	.306
.4	1.008	.407
.5	1.002	.508
.6	.997	.608
.7	.992	.707
.8	.986	.806
.9	.981	.905
1	.975	1.002
1.1	.97	1.1
1.2	.937	1.195
1.3	.901	1.287
1.4	.88	1.376
1.5	.881	1.464
1.6	.882	1.553
1.7	.884	1.641
1.8	.885	1.729
1.9	.886	1.818
2	.887	1.907
2.1	.888	1.996
2.2	.887	2.084
2.3	.865	2.172
2.4	.843	2.258
2.5	.821	2.341
2.6	.799	2.422
2.7	.777	2.501
2.8	.755	2.577
2.9	.733	2.652

3	.718	2.724
3.1	.716	2.796
3.2	.713	2.868
3.3	.71	2.939
3.4	.708	3.01
3.5	.705	3.08
3.6	.702	3.151
3.7	.7	3.221
3.8	.697	3.291
3.9	.694	3.361
4	.692	3.43
4.1	.676	3.498
4.2	.619	3.563
4.3	.616	3.625
4.4	.613	3.686
4.5	.61	3.748
4.6	.608	3.809
4.7	.605	3.869
4.8	.602	3.93
4.9	.599	3.99
5	.596	4.05
5.1	.593	4.109
5.2	.591	4.168
5.3	.588	4.227
5.4	.585	4.286
5.5	.582	4.344
5.6	.577	4.402
5.7	.55	4.459
5.8	.524	4.512
5.9	.497	4.564
6	.47	4.612
6.1	.459	4.658
6.2	.458	4.704
6.3	.457	4.75
6.4	.456	4.796
6.5	.456	4.842
6.6	.455	4.887
6.7	.454	4.933
6.8	.453	4.978
6.9	.452	5.023

7	.451	5.069
7.1	.451	5.114
7.2	.45	5.159
7.3	.424	5.203
7.4	.393	5.243
7.5	.362	5.281
7.6	.33	5.316
7.7	.299	5.347
7.8	.287	5.377
7.9	.284	5.405
8	.281	5.434
8.1	.304	5.463
8.2	.335	5.495
8.3	.324	5.528
8.4	.312	5.56
8.5	.301	5.59
8.6	.289	5.62
8.7	.278	5.648
8.8	.266	5.676
8.9	.255	5.702
9	.244	5.727
9.1	.232	5.751
9.2	.221	5.773
9.3	.209	5.795
9.4	.198	5.815
9.5	.186	5.834
9.6	.197	5.854
9.7	.217	5.874
9.8	.211	5.896
9.9	.205	5.917
10	.199	5.937
10.1	.193	5.957
10.2	.187	5.976
10.3	.181	5.994
10.4	.175	6.012
10.5	.169	6.029
10.6	.163	6.046
10.7	.157	6.062
10.8	.151	6.077
10.9	.146	6.092

11	.14	6.107
11.1	.134	6.12
11.2	.128	6.133
11.3	.122	6.146
11.4	.116	6.158
11.5	.11	6.169
11.6	.104	6.18
11.7	.098	6.19
11.8	.092	6.2
11.9	.086	6.209
12	.081	6.217
12.1	.075	6.225
12.2	.069	6.232
12.3	.063	6.239
12.4	.057	6.245
12.5	.051	6.25
12.6	.045	6.255
12.7	.039	6.259
12.8	.033	6.263
12.9	.027	6.266
13	.021	6.269
13.1	.015	6.271
13.2	.01	6.272
13.3	.004	6.273

TEST 10

32 POUND HE CALIBRATION
6 O'CLOCK LEG, 7.5 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	380	0
.1	217.944	29.897
.2	86.018	45.095
.3	74.609	53.126
.4	63.2	60.017
.5	51.79	65.766
.6	40.381	70.375
.7	28.972	73.843
.8	17.563	76.169
.9	15.456	77.82
1	19.55	79.571
1.1	23.643	81.73
1.2	25.076	84.166
1.3	22.517	86.546
1.4	19.958	88.67
1.5	17.4	90.538
1.6	14.841	92.15
1.7	12.282	93.506
1.8	9.723	94.606
1.9	7.164	95.451
2	4.605	96.039
2.1	2.047	96.372

TEST 10

32 POUND HE CALIBRATION
6 O'CLOCK LEG, 13 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	97.6	0
.1	65.655	8.162
.2	42.066	13.548
.3	25.825	16.943
.4	29.7	19.719
.5	21.325	22.27
.6	25.342	24.604
.7	28.388	27.29
.8	25.611	29.99
.9	22.833	32.413
1	20.055	34.557
1.1	17.277	36.424
1.2	15.84	38.08
1.3	14.553	39.599
1.4	13.265	40.99
1.5	11.977	42.252
1.6	10.689	43.386
1.7	9.401	44.39
1.8	8.113	45.266
1.9	6.825	46.013
2	5.537	46.631
2.1	4.25	47.121
2.2	2.962	47.481
2.3	1.674	47.713
2.4	.386	47.816

TEST 10

32 POUND HE CALIBRATION
6 O'CLOCK LEG, 25 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	26.2	0
.1	17.118	2.165
.2	17.125	3.878
.3	17.831	5.625
.4	15.749	7.304
.5	14.315	8.808
.6	13.852	10.216
.7	13.39	11.578
.8	12.928	12.894
.9	12.466	14.164
1	12.004	15.388
1.1	11.542	16.565
1.2	11.08	17.696
1.3	10.617	18.781
1.4	10.155	19.82
1.5	9.693	20.812
1.6	9.231	21.758
1.7	8.769	22.658
1.8	8.307	23.512
1.9	7.844	24.32
2	7.382	25.081
2.1	6.92	25.796
2.2	6.458	26.465
2.3	5.996	27.088
2.4	5.534	27.664
2.5	5.071	28.195
2.6	4.609	28.679
2.7	4.209	29.12
2.8	4.056	29.533
2.9	3.904	29.931

3	3.751	30.314
3.1	3.599	30.682
3.2	3.446	31.034
3.3	3.294	31.371
3.4	3.141	31.693
3.5	2.989	31.999
3.6	2.836	32.291
3.7	2.684	32.567
3.8	2.531	32.827
3.9	2.379	33.073
4	2.226	33.303
4.1	2.074	33.518
4.2	1.921	33.718
4.3	1.769	33.903
4.4	1.616	34.072
4.5	1.464	34.226
4.6	1.311	34.365
4.7	1.159	34.488
4.8	1.006	34.597
4.9	.854	34.69
5	.701	34.768
5.1	.549	34.83
5.2	.396	34.877
5.3	.244	34.909
5.4	.091	34.926

TEST 10

32 POUND HE CALIBRATION
6 O'CLOCK LEG, 40 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	9.38	0
.1	7.923	.865
.2	7.466	1.634
.3	7.4	2.^78
.4	7.212	3.108
.5	7.024	3.82
.6	6.836	4.513
.7	6.648	5.187
.8	6.459	5.843
.9	6.271	6.479
1	6.083	7.097
1.1	5.895	7.696
1.2	5.707	8.276
1.3	5.519	8.837
1.4	5.331	9.38
1.5	5.142	9.904
1.6	4.954	10.409
1.7	4.766	10.895
1.8	4.578	11.362
1.9	4.39	11.81
2	4.202	12.24
2.1	4.014	12.651
2.2	3.913	13.047
2.3	3.901	13.438
2.4	3.889	13.828
2.5	3.877	14.216
2.6	3.864	14.603
2.7	2.454	14.919
2.8	4.255	15.254
2.9	3.336	15.634

3	2.905	15.946
3.1	2.483	16.215
3.2	3.246	16.502
3.3	3.627	16.846
3.4	3.12	17.183
3.5	3.327	17.505
3.6	2.637	17.804
3.7	2.524	18.062
3.8	2.318	18.314
3.9	2.512	18.565
4	2.506	18.816
4.1	2.5	19.067
4.2	2.494	19.316
4.3	2.488	19.566
4.4	2.482	19.814
4.5	2.476	20.062
4.6	2.47	20.309
4.7	2.258	20.546
4.8	2.046	20.761
4.9	1.834	20.955
5	1.622	21.128
5.1	1.41	21.279
5.2	1.198	21.41
5.3	1.164	21.528
5.4	1.175	21.645
5.5	1.094	21.758
5.6	1.013	21 864
5.7	.932	21.961
5.8	.85	22.05
5.9	.769	22.131
6	.688	22.204
6.1	.607	22.269
6.2	.526	22.326
6.3	.445	22.374
6.4	.364	22.415
6.5	.283	22.447
6.6	.202	22.472
6.7	.121	22.488
6.8	.04	22.496

TEST 10

32 POUND HE CALIBRATION
6 O'CLOCK LEG, 70 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	3.38	0
.1	3.024	.32
.2	2.984	.62
.3	2.944	.917
.4	2.904	1.209
.5	2.864	1.497
.6	2.824	1.782
.7	2.784	2.062
.8	2.744	2.339
.9	2.704	2.611
1	2.664	2.879
1.1	2.624	3.144
1.2	2.584	3.404
1.3	2.544	3.661
1.4	2.504	3.913
1.5	2.464	4.161
1.6	2.424	4.406
1.7	2.384	4.646
1.8	2.344	4.883
1.9	2.304	5.115
2	2.264	5.343
2.1	2.224	5.568
2.2	2.184	5.788
2.3	2.144	6.005
2.4	2.104	6.217
2.5	2.064	6.425
2.6	^.024	6.63
2.7	1.984	6.83
2.8	1.944	7.027
2.9	1.904	7.219

3	1.864	7.407
3.1	1.824	7.592
3.2	1.784	7.772
3.3	1.744	7.949
3.4	1.704	8.121
3.5	1.664	8.289
3.6	1.624	8.454
3.7	1.584	8.614
3.8	1.544	8.771
3.9	1.504	8.923
4	1.464	9.071
4.1	1.424	9.216
4.2	1.384	9.356
4.3	1.344	9.493
4.4	1.425	9.631
4.5	1.385	9.772
4.6	1.344	9.908
4.7	1.304	10.041
4.8	1.263	10.169
4.9	1.222	10.293
5	1.182	10.413
5.1	1.141	10.53
5.2	1.101	10.642
5.3	1.06	10.75
5.4	1.019	10.854
5.5	.979	10.954
5.6	.938	11.05
5.7	.898	11.142
5.8	.976	11.235
5.9	.955	11.332
6	.933	11.426
6.1	.911	11.519
6.2	.889	11.609
6.3	.867	11.697
6.4	.845	11.782
6.5	.824	11.866
6.6	.802	11.947
6.7	.78	12.026
6.8	.758	12.103
6.9	.736	12.178

7	.714	12.25
7.1	.692	12.321
7.2	.671	12.389
7.3	.649	12.455
7.4	.627	12.519
7.5	.605	12.581
7.6	.583	12.64
7.7	.561	12.697
7.8	.54	12.752
7.9	.518	12.805
8	.496	12.856
8.1	.474	12.905
8.2	.452	12.951
8.3	.43	12.995
8.4	.409	13.037
8.5	.387	13.077
8.6	.365	13.115
8.7	.343	13.15
8.8	.321	13.183
8.9	.299	13.214
9	.278	13.243
9.1	.256	13.27
9.2	.234	13.295
9.3	.29	13.321
9.4	.342	13.352
9.5	.306	13.385
9.6	.27	13.414
9.7	.234	13.439
9.8	.198	13.461
9.9	.162	13.479
10	.126	13.493
10.1	.09	13.504
10.2	.054	13.511
10.3	.018	13.515

TEST 10

32 POUND HE CALIBRATION
6 O'CLOCK LEG, 140 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	1.183	0
.1	1.113	.114
.2	1.044	.222
.3	.974	.323
.4	.943	.419
.5	.969	.515
.6	.995	.613
.7	1.022	.714
.8	1.048	.817
.9	1.074	.924
1	1.1	1.002
1.1	1.052	1.14
1.2	1.007	1.243
1.3	.997	1.343
1.4	.986	1.442
1.5	.976	1.541
1.6	.965	1.638
1.7	.954	1.734
1.8	.944	1.829
1.9	.933	1.922
2	.923	2.015
2.1	.912	2.107
2.2	.902	2.198
2.3	.891	2.288
2.4	.881	2.376
2.5	.87	2.464
2.6	.86	2.55
2.7	.849	2.636
2.8	.838	2.72
2.9	.828	2.804

3	.817	2.886
3.1	.807	2.967
3.2	.796	3.047
3.3	.786	3.127
3.4	.775	3.205
3.5	.765	3.282
3.6	.754	3.358
3.7	.744	3.433
3.8	.733	3.506
3.9	.722	3.579
4	.712	3.651
4.1	.701	3.722
4.2	.691	3.791
4.3	.631	3.858
4.4	.612	3.92
4.5	.621	3.981
4.6	.63	4.044
4.7	.639	4.108
4.8	.648	4.172
4.9	.658	4.237
5	.667	4.304
5.1	.676	4.371
5.2	.622	4.436
5.3	.611	4.498
5.4	.6	4.558
5.5	.588	4.618
5.6	.577	4.676
5.7	.566	4.733
5.8	.554	4.789
5.9	.543	4.844
6	.532	4.898
6.1	.52	4.95
6.2	.509	5.002
6.3	.498	5.052
6.4	.486	5.102
6.5	.475	5.15
6.6	.464	5.197
6.7	.452	5.242
6.8	.481	5.289
6.9	.473	5.337

7	.466	5.384
7.1	.459	5.43
7.2	.452	5.476
7.3	.444	5.521
7.4	.437	5.565
7.5	.43	5.608
7.6	.423	5.651
7.7	.416	5.693
7.8	.408	5.734
7.9	.401	5.775
8	.394	5.814
8.1	.387	5.854
8.2	.379	5.892
8.3	.372	5.93
8.4	.365	5.966
8.5	.358	6.003
8.6	.351	6.038
8.7	.343	6.073
8.8	.336	6.107
8.9	.329	6.14
9	.322	6.173
9.1	.314	6.205
9.2	.307	6.236
9.3	.3	6.266
9.4	.293	6.296
9.5	.286	6.325
9.6	.278	6.353
9.7	.271	6.381
9.8	.264	6.407
9.9	.257	6.434
10	.249	6.459
10.1	.242	6.483
10.2	.235	6.507
10.3	.228	6.531
10.4	.221	6.553
10.5	.213	6.575
10.6	.206	6.596
10.7	.199	6.616
10.8	.192	6.636
10.9	.184	6.655

11	.177	6.673
11.1	.17	6.69
11.2	.163	6.707
11.3	.156	6.723
11.4	.148	6.738
11.5	.141	6.753
11.6	.134	6.766
11.7	.127	6.779
11.8	.119	6.792
11.9	.112	6.803
12	.105	6.814
12.1	.098	6.824
12.2	.091	6.834
12.3	.083	6.843
12.4	.076	6.851
12.5	.069	6.858
12.6	.062	6.865
12.7	.054	6.87
12.8	.047	6.876
12.9	.04	6.88
13	.033	6.884
13.1	.026	6.887
13.2	.018	6.889
13.3	.011	6.89
13.4	.004	6.891

TEST 10

32 POUND HE CALIBRATION
2 O'CLOCK LEG, 25 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	25	0
.1	21.37	2.318
.2	17.74	4.274
.3	18	6.061
.4	17.909	7.856
.5	13.7	9.437
.6	16.881	10.966
.7	12.797	12.45
.8	12.916	13.735
.9	12.471	15.005
1	11.286	16.193
1.1	10.595	17.287
1.2	9.903	18.312
1.3	9.212	19.267
1.4	8.52	20.154
1.5	7.828	20.972
1.6	7.137	21.72
1.7	6.445	22.399
1.8	7.073	23.075
1.9	6.838	23.771
2	6.6	24.443
2.1	6.363	25.091
2.2	6.125	25.715
2.3	5.888	26.316
2.4	5.65	26.893
2.5	5.412	27.446
2.6	5.175	27.976
2.7	4.937	28.481
2.8	5.434	29
2.9	4.198	29.481

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3	4.025	29.893
3.1	3.852	30.287
3.2	3.68	30.663
3.3	3.507	31.023
3.4	3.334	31.365
3.5	3.162	31.69
3.6	2.989	31.997
3.7	2.816	32.287
3.8	2.644	32.56
3.9	2.471	32.816
4	2.298	33.055
4.1	2.126	33.276
4.2	1.953	33.48
4.3	1.78	33.667
4.4	1.608	33.836
4.5	1.435	33.988
4.6	1.262	34.123
4.7	1.09	34.241
4.8	1.882	34.389
4.9	1.214	34.544
5	1.125	34.661
5.1	1.037	34.77
5.2	.948	34.869
5.3	.859	34.959
5.4	.771	35.041
5.5	.682	35.113
5.6	.593	35.177
5.7	.505	35.232
5.8	.416	35.278
5.9	.328	35.316
6	.239	35.344
6.1	.15	35.363
6.2	.062	35.374

TEST 10

32 POUND HE CALIBRATION
2 O'CLOCK LEG, 40 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	8.83	0
.1	7.548	.818
.2	6.734	1.533
.3	6.62	2.2
.4	6.506	2.857
.5	6.391	3.502
.6	6.277	4.135
.7	6.163	4.757
.8	6.049	5.368
.9	5.935	5.967
1	5.821	6.555
1.1	5.707	7.131
1.2	5.593	7.696
1.3	5.478	8.25
1.4	5.364	8.792
1.5	5.25	9.323
1.6	5.136	9.842
1.7	5.022	10.35
1.8	4.908	10.847
1.9	4.794	11.332
2	4.594	11.801
2.1	4.357	12.249
2.2	4.121	12.673
2.3	3.982	13.078
2.4	3.886	13.471
2.5	3.789	13.855
2.6	3.693	14.229
2.7	3.597	14.594
2.8	3.5	14.949
2.9	3.404	15.294

3	3.307	15.63
3.1	3.211	15.956
3.2	3.115	16.272
3.3	3.018	16.579
3.4	2.922	16.876
3.5	2.826	17.163
3.6	2.729	17.441
3.7	2.633	17.709
3.8	2.537	17.968
3.9	2.44	18.217
4	2.344	18.456
4.1	2.247	18.685
4.2	2.151	18.905
4.3	2.055	19.116
4.4	1.958	19.316
4.5	1.862	19.508
4.6	1.766	19.689
4.7	1.669	19.861
4.8	1.573	20.023
4.9	1.477	20.175
5	1.38	20.318
5.1	1.284	20.452
5.2	1.187	20.575
5.3	1.091	20.689
5.4	.995	20.794
5.5	.921	20.889
5.6	.87	20.979
5.7	.819	21.063
5.8	.769	21.143
5.9	.718	21.217
6	.667	21.287
6.1	.616	21.351
6.2	.565	21.41
6.3	.514	21.464
6.4	.464	21.513
6.5	.413	21.557
6.6	.362	21.595
6.7	.311	21.629
6.8	.26	21.658
6.9	.209	21.681

7	.158	21.7
7.1	.108	21.713
7.2	.057	21.721
7.3	.006	21.725
7.4	-.044	21.723

TEST 10

3½ POUND HE CALIBRATION
2 O'CLOCK LEG, 70 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	3.54	0
.1	3.084	.331
.2	2.713	.621
.3	2.681	.89
.4	2.649	1.157
.5	2.618	1.42
.6	2.586	1.681
.7	2.554	1.938
.8	2.522	2.192
.9	2.49	2.442
1	2.458	2.69
1.1	2.427	2.934
1.2	2.395	3.175
1.3	2.363	3.413
1.4	2.331	3.648
1.5	2.299	3.879
1.6	2.268	4.108
1.7	2.236	4.333
1.8	2.204	4.555
1.9	2.172	4.774
2	2.14	4.99
2.1	2.108	5.202
2.2	2.077	5.411
2.3	2.045	5.617
2.4	2.013	5.82
2.5	1.981	6.02
2.6	1.949	6.217
2.7	1.917	6.41
2.8	1.886	6.6
2.9	1.854	6.787

3	1.822	6.971
3.1	1.79	7.152
3.2	1.758	7.329
3.3	1.726	7.503
3.4	1.695	7.675
3.5	1.663	7.842
3.6	1.631	8.007
3.7	1.599	8.169
3.8	1.567	8.327
3.9	1.535	8.482
4	1.504	8.634
4.1	1.472	8.783
4.2	1.44	8.929
4.3	1.408	9.071
4.4	1.376	9.21
4.5	1.344	9.346
4.6	1.313	9.479
4.7	1.281	9.609
4.8	1.249	9.736
4.9	1.217	9.859
5	1.185	9.979
5.1	1.153	10.096
5.2	1.122	10.21
5.3	1.09	10.321
5.4	1.058	10.428
5.5	1.026	10.532
5.6	.994	10.633
5.7	.962	10.731
5.8	.931	10.826
5.9	.899	10.917
6	.867	11.006
6.1	.835	11.091
6.2	.803	11.173
6.3	.771	11.252
6.4	.74	11.327
6.5	.708	11.4
6.6	.676	11.469
6.7	.644	11.535
6.8	.612	11.598
6.9	.58	11.658

7	.549	11.714
7.1	.517	11.767
7.2	.485	11.817
7.3	.463	11.865
7.4	.478	11.912
7.5	.493	11.961
7.6	.508	12.011
7.7	.524	12.062
7.8	.539	12.115
7.9	.554	12.17
8	.569	12.226
8.1	.585	12.284
8.2	.6	12.343
8.3	.615	12.404
8.4	.63	12.467
8.5	.571	12.527
8.6	.398	12.575
8.7	.226	12.606
8.8	.19	12.627
8.9	.238	12.649
9	.235	12.672
9.1	.231	12.696
9.2	.228	12.719
9.3	.225	12.741
9.4	.222	12.764
9.5	.219	12.786
9.6	.215	12.808
9.7	.212	12.829
9.8	.191	12.849
9.9	.097	12.864
10	.057	12.871
10.1	.052	12.877
10.2	.047	12.882
10.3	.042	12.886
10.4	.038	12.89
10.5	.033	12.894
10.6	.028	12.897
10.7	.023	12.9
10.8	.019	12.902
10.9	.014	12.903
11	.009	12.905
11.1	.004	12.905

TEST 10

32 POUND HE CALIBRATION
2 O'CLOCK LEG, 140 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	1.01	0
.1	1.002	.1
.2	.995	.2
.3	.988	.299
.4	.981	.398
.5	.973	.495
.6	.966	.593
.7	.959	.689
.8	.952	.784
.9	.945	.879
1	.937	.973
1.1	.93	1.067
1.2	.909	1 159
1.3	.885	1.249
1.4	.862	1.336
1.5	.839	1.421
1.6	.831	1.505
1.7	.835	1.588
1.8	.838	1.672
1.9	.841	1.756
2	.844	1.84
2.1	.848	1.925
2.2	.842	2.009
2.3	.824	2.093
2.4	.806	2.174
2.5	.787	2.254
2.6	.769	2.332
2.7	.751	2.408
2.8	.732	2.482
2.9	.714	2.554

3	.7	2.625
3.1	.702	2.695
3.2	.704	2.766
3.3	.706	2.836
3.4	.708	2.907
3.5	.711	2.978
3.6	.713	3.049
3.7	.715	3.121
3.8	.717	3.192
3.9	.719	3.264
4	.656	3.333
4.1	.635	3.397
4.2	.628	3.461
4.3	.622	3.523
4.4	.616	3.585
4.5	.61	3.647
4.6	.604	3.707
4.7	.598	3.767
4.8	.592	3.827
4.9	.586	3.886
5	.58	3.944
5.1	.573	4.002
5.2	.567	4.059
5.3	.561	4.115
5.4	.555	4.171
5.5	.536	4.226
5.6	.477	4.277
5.7	.473	4.324
5.8	.469	4.371
5.9	.465	4.418
6	.461	4.464
6.1	.457	4.51
6.2	.453	4.556
6.3	.449	4.601
6.4	.445	4.646
6.5	.441	4.69
6.6	.437	4.734
6.7	.433	4.778
6.8	.429	4.821
6.9	.425	4.864

7	.421	4.906
7.1	.405	4.948
7.2	.376	4.987
7.3	.346	5.023
7.4	.317	5.056
7.5	.288	5.086
7.6	.258	5.114
7.7	.257	5.139
7.8	.267	5.166
7.9	.278	5.193
8	.288	5.221
8.1	.299	5.251
8.2	.309	5.281
8.3	.32	5.313
8.4	.303	5.344
8.5	.286	5.373
8.6	.269	5.401
8.7	.252	5.427
8.8	.235	5.452
8.9	.218	5.474
9	.202	5.495
9.1	.185	5.515
9.2	.168	5.532
9.3	.21	5.551
9.4	.21	5.572
9.5	.21	5.593
9.6	.21	5.614
9.7	.21	5.635
9.8	.21	5.656
9.9	.21	5.677
10	.21	5.698
10.1	.202	5.719
10.2	.193	5.739
10.3	.184	5.758
10.4	.176	5.776
10.5	.167	5.793
10.6	.158	5.809
10.7	.15	5.825
10.8	.141	5.839
10.9	.132	5.853

11	.124	5.866
11.1	.115	5.878
11.2	.106	5.889
11.3	.099	5.899
11.4	.096	5.909
11.5	.092	5.919
11.6	.089	5.928
11.7	.086	5.936
11.8	.082	5.945
11.9	.079	5.953
12	.076	5.961
12.1	.073	5.968
12.2	.069	5.975
12.3	.066	5.982
12.4	.063	5.989
12.5	.06	5.995
12.6	.042	6
12.7	.025	6.004
12.8	.008	6.005

Appendix B
RECOMMENDED ADDITIONAL TEST PROGRAM

SEMI-CONFINED TESTS WITH VERTICAL WALLS

The test configuration recommended for this condition is similar to that used in the previously conducted semi-confined tests except for the size of the cylindrical tank and the nature of the ignition source. A 6-ft diameter tank is recommended instead of a 3-ft tank since it is believed that mixing is enhanced with somewhat thinner layers of propellants (3 in. instead of 12 in.) which in turn should help minimize the ignition problem.

For ignition, two alternate sources are recommended. The first consists of six 6-ft long strands of primacord stretched radially across the tank at angles of 30 degrees to each other with one end of each strand fastened at the bottom and the other at a height of 3 in. (the height of quiescent liquid propellants). The continuous nature of this ignition source gives a much higher probability that the initiator will be in contact with those portions of the mixture which are susceptible to ignition than did the previously used two point ignition system. The second source consists of 10 detonator caps distributed uniformly throughout the volume of the mixed propellant. This arrangement does not distribute the initiating source nearly as well as the primacord but each individual source is somewhat stronger.

A series of four tests with configuration is recommended initially: two with the primacord and two with the detonators, both using the sequenced filling method as used for Test No. 4. Subsequently, two additional tests should be run using whichever ignition source gives the highest yields and using the simultaneous filling method as used for Test No. 6.

Since a yield as high as 38% (Test No. 4) was obtained with only two detonators, it is believed that the recommended ignition sources should be sufficient to obtain the full explosive potential of the propellant mixture. However, depending on the nature of the results it is possible that still other variations may be necessary. Also, if the analysis of potential ignition sources is made, as recommended, and if their strength and/or distribution is significantly different than those already tested it may be desirable to conduct additional tests using ignition sources with characteristics similar to those of the potential sources.

It should be noted that the above recommended program is not intended to evaluate in great detail the dependence of yield on initiator strength and distribution but rather to determine its overall nature and to obtain the maximum explosive yield. A more detailed evaluation would be interesting but would require a great many more tests and at present is not justifiable.

SEMI-CONFINED TESTS WITHOUT VERTICAL WALLS

The ideal test configuration for this condition would consist of an infinite flat impermeable surface in the center of which the propellants would be simultaneously released from two closely adjacent pipes, of as large a diameter as credible. Ignition should occur at the instant that all the propellants have been released. Being cryogenic, the propellants will spread with little friction because of the presence of a gas layer at the impermeable surface created by the evaporating gases. With credible pipe sizes on the order of two in., the release time is on the order of 20 sec, and the size of the expanding pool will be very large. Experimentally, it is impractical to simulate this condition exactly. However, a reasonably close approximation which is on the conservative side (i.e., which should give higher yields) is to use a 20- to 30-ft diameter flat circular (or square) surface with a lip a few in. high around it to prevent escape of any propellants. Again ignition should take place within a few seconds after all the propellants are released.

If the primacord ignition source recommended for the semi-confined tests with vertical walls works satisfactorily, its use is also recommended here with from four to six strands stretched radially across the test area.

A series of four tests is recommended initially for this configuration with an additional four tests as backup to test modification in the test condition that may become desirable as a result of the first four tests.

Appendix C
SEMI-CONFINED TESTS 4 AND 6

Presented in this Appendix are the test descriptions and digitized data for the two semi-confined tests (Numbers 4 and 6) which resulted in an explosion.

TEST 4

In this test, liquid CO was pressure forced by helium from an underground storage tank into a 3-ft diameter, 3-ft high thin wall aluminum test tank.

From earlier calibration runs, it was est· ated that approximately 6 in. (180 lbs) of liquid CO remained in the test tank after the fueling operation which was accomplished in 25 seconds. After a delay of three seconds, liquid N_2O was placed on top of the CO in a similar fueling operation which also took 25 seconds. From earlier calibration runs, it was estimated that approximately 6 in. (270 lbs) of N_2O remained in the test tank. The resulting mixture of propellants was detonated two second after completion of the N_2O fueling operation by two blasting caps placed in the side of the test tank.

This test was conducted on a 6 in. thick steel plate located at ground zero. This pad was slightly dished as shown in the construction photo Fig. C-1.

The resulting blast from this test destroyed this pad, driving a large section of the pad approximately 30 in. into the ground. See posttest photos Fig. C-2.

The digitized data for this test follows:

Fig. C-1. Test Pad for Test 4 (Pre Test)

Fig. C-2. Test Pad for Test 4 (Posttest)

TEST 4

2 O'CLOCK LEG, DISTANCE 25 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	89.9	0
.1	72.011	8.095
.2	61.936	14.792
.3	75.05	21.642
.4	54.019	28.095
.5	49.475	33.27
.6	44.931	37.99
.7	40.387	42.256
.8	35.843	46.068
.9	31.3	49.425
1	32.595	52.62
1.1	32.446	55.872
1.2	32.297	59.109
1.3	32.148	62.332
1.4	32	65.539
1.5	26.892	68.484
1.6	21.785	70.918
1.7	17.759	72.895
1.8	18.055	74.686
1.9	18.351	76.506
2	18.648	78.356
2.1	18.944	80.236
2.2	19.24	82.145
2.3	16.351	83.924
2.4	12.665	85.375
2.5	8.979	86.457
2.6	5.293	87.171
2.7	1.607	87.516
2.8	.993	87.646
2.9	.984	87.745
3	.974	87.843
3.1	.965	87.94
3.2	.955	88.036
3.3	.946	88.131
3.4	.937	88.225

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3.5	.927	88.318
3.6	.918	88.411
3.7	.908	88.502
3.8	.899	88.593
3.9	.89	88.682
4	.88	88.771
4.1	.871	88.858
4.2	.861	88.945
4.3	.852	89.031
4.4	.843	89.115
4.5	.833	89.199
4.6	.801	89.281
4.7	.753	89.359
4.8	.705	89.432
4.9	.657	89.5
5	.609	89.563
5.1	.561	89.622
5.2	.513	89.675
5.3	.465	89.724
5.4	.417	89.768
5.5	.369	89.808
5.6	.55	89.854
5.7	.511	89.907
5.8	.471	89.956
5.9	.432	90.001
6	.393	90.042
6.1	.353	90.08
6.2	.314	90.113
6.3	.275	90.143
6.4	.235	90.168
6.5	.196	90.19
6.6	.157	90.207
6.7	.117	90.221
6.8	.078	90.231
6.9	.039	90.237
7	0	90.239

TEST 4

2 O'CLOCK LEG, DISTANCE 70 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	7	0
.1	6.505	.675
.2	5.734	1.287
.3	5.395	1.843
.4	5.328	2.379
.5	5.26	2.909
.6	5.192	3.432
.7	5.125	3.947
.8	5.057	4.457
.9	4.989	4.959
1	4.922	5.455
1.1	4.854	5.943
1.2	4.786	6.426
1.3	4.719	6.901
1.4	4.651	7.369
1.5	4.583	7.831
1.6	4.516	8.286
1.7	4.448	8.734
1.8	4.38	9.176
1.9	4.316	9.611
2	4.285	10.041
2.1	4.253	10.468
2.2	4.221	10.892
2.3	4.19	11.312
2.4	4.158	11.73
2.5	4.126	12.144
2.6	4.095	12.555
2.7	4.063	12.963
2.8	4.031	13.368
2.9	4	13.769
3	3.968	14.168
3.1	3.937	14.563
3.2	3.905	14.955
3.3	3.873	15.344
3.4	3.842	15.73

3.5	3.81	16.113
3.6	3.778	16.492
3.7	3.747	16.868
3.8	3.715	17,241
3.9	3.683	17.611
4	3.652	17.978
4.1	5.284	18.425
4.2	4.328	18.906
4.3	3.637	19.304
4.4	3.561	19.664
4.5	3.485	20.016
4.6	3.409	20.361
4.7	3.333	20.698
4.8	3.257	21.028
4.9	3.181	21.35
5	3.105	21.664
5.1	3.03	21.971
5.2	2.954	22.27
5.3	2.878	22.562
5.4	2.802	22.846
5.5	2.726	23.122
5.6	2.65	23.391
5.7	2.574	23.652
5.8	2.498	23.906
5.9	2.422	24.152
6	2.346	24.391
6.1	2.271	24.621
6.2	2.195	24.845
6.2	2.18	25.064
6.4	2.18	25.282
6.5	2.18	25.5
6.6	2.18	25.718
6.7	2.18	25.936
6.8	2.18	26.154
6.9	1.836	26.354
7	1.802	26.536
7.1	1.768	26.715
7.2	1.733	26.89
7.3	1.699	27.062
7.4	1.665	27.23

7.5	1.631	27.395
7.6	1 596	27.556
7.7	1.562	27.714
7.8	1.528	27.869
7.9	1.494	28.02
8	1.459	28.167
8.1	1.425	28.312
8.2	1.391	28.453
8.3	1.357	28.59
8.4	1.414	28.729
8.5	1.562	28.877
8.6	1.71	29.041
8.7	1.772	29.215
8.8	1.704	29.389
8.9	1.635	29.556
9	1.567	29.716
9.1	1.499	29.87
9.2	1.43	30.016
9.3	1.362	30.156
9.4	1.294	30.289
9.5	1.225	30.415
9.6	1.157	30.534
9.7	1.089	30.646
9.8	1.02	30.752
9.9	.952	30.85
10	.884	30.942
10.1	1.2	31.046
10.2	1.196	31.166
10.3	.891	31.271
10.4	.794	31.355
10.5	.786	31.434
10.6	.778	31.512
10.7	.77	31.59
10.8	.763	31.666
10.9	.755	31.742
11	.747	31.817
11.1	.739	31.892
11.2	.731	31.965
11.3	.723	32.038
11.4	.715	32.11

11.5	.707	32.181
11.6	.7	32.252
11.7	.692	32.321
11.8	.684	32.39
11.9	.676	32.458
12	.668	32.525
12.1	.66	32.592
12.2	.652	32.658
12.3	.645	32.722
12.4	.637	32.787
12.5	.629	32.85
12.6	.621	32.912
12.7	.613	32.974
12.8	.605	33.035
12.9	.597	33.095
13	.59	33.155
13.1	.582	33.213
13.2	.574	33.271
13.3	.566	33.328
13.4	.558	33.384
13.5	.55	33.44
13.6	.542	33.495
13.7	.534	33.548
13.8	.527	33.602
13.9	.519	33.654
14	.511	33.705
14.1	.503	33.756
14.2	.495	33.806
14.3	.487	33.855
14.4	.479	33.904
14.5	.472	33.951
14.6	.464	33.998
14.7	.456	34.044
14.8	.446	34.089
14.9	.431	34.133
15	.415	34.176

TEST 4

2 O'CLOCK LEG, DISTANCE 140 feet

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	2.08	0
1	1.683	1.881
2	1.555	3.501
3	1.413	4.985
4	1.267	6.326
5	1.2	7.559
6	1.031	8.675
7	1.115	9.749
8	.95	10.782
9	.786	11.651
10	.805	12.447
11	.753	13.227
12	.675	13.941
13	.598	14.578
14	.52	15.138
15	.443	15.62
16	.365	16.024
17	.287	16.351
18	.231	16.610
19	.181	16.816
20	.13	16.972
21	.08	17.078
22	.03	17.133

TEST 4

6 O'CLOCK LEG, DISTANCE 7.5 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	476	0
.1	180.307	32.815
.2	83	45.98
.3	46.714	52.466
.4	38.857	56.745
.5	140.2	65.697
.6	76	76.507

TEST 4

6 O'CLOCK LEG, DISTANCE 13 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	100	0
.1	138.428	11.921
.2	114.29	24.557
.3	67.2	33.631
.4	49.661	39.475
.5	32.123	43.564
.6	18.963	46.118
.7	12.373	47.685
.8	9.266	48.767
.9	14.288	49.945
1	12.133	51.266
1.1	2.8	52.013

TEST 4

6 O'CLOCK LEG, DISTANCE 25 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	73.4	0
.1	53.645	6.352
.2	42.536	11.161
.3	41.992	15.387
.4	41.449	19.559
.5	40.905	23.677
.6	40.361	27.741
.7	39.817	31.749
.8	36.107	35.546
.9	35.464	39.124
1	34.821	42.639
1.1	32.363	45.998
1.2	32.12	49.222
1.3	31.008	52.378
1.4	29.128	55.385
1.5	27.248	58.204
1.6	25.368	60.835
1.7	23.488	63.278
1.8	21.608	65.532
1.9	19.728	67.599
2	17.848	69.478
2.1	15.968	71.169
2.2	14.088	72.672
2.3	13.354	74.044
2.4	12.749	75.349
2.5	12.143	76.594
2.6	11.537	77.778
2.7	10.931	78.901
2.8	10.325	79.964
2.9	9.72	80.966

3	9.114	81.908
3.1	8.508	82.789
3.2	7.902	83.61
3.3	7.393	84.375
3.4	6.98	85.093
3.5	6.567	85.771
3.6	6.154	86.407
3.7	5.741	87.001
3.8	5.328	87.555
3.9	4.915	88.067
4	4.502	88.538
4.1	4.089	88.968
4.2	3.676	89.356
4.3	3.263	89.703
4.4	2.85	90.008
4.5	2.436	90.273
4.6	2.023	90.496
4.7	1.61	90.678
4.8	1.197	90.818
4.9	.784	90.917
5	.371	90.975

TEST 4

6 O'CLOCK LEG, DISTANCE 40 FEET

TIME (msec)	PRESSURE	IMPULSE (psi-msec)
0	20.2	0
.1	17.104	1.865
.2	14.009	3.42
.3	16.142	4.928
.4	16.166	6.544
.5	14.881	8.096
.6	14.518	9.566
.7	14.154	11.
.8	13.79	12.397
.9	13.427	13.758
1	13.063	15.082
1.1	12.7	16.371
1.2	12.336	17.622
1.3	11.972	18,838
1.4	11.609	20.017
1.5	11.245	21.16
1.6	10.881	22.266
1.7	10.518	23,336
1.8	10.154	24.37
1.9	9.79	25.367
2	9.427	26.328
2.1	9.084	27.253
2.2	8.927	28.154
2.3	8.771	29.039
2.4	8.614	29.908
2.5	8.457	30.762
2.6	8.301	31.6
2.7	8.144	32.422
2.8	7.987	33.229
2.9	7.831	34.02
3	7.674	34.795
3.1	7.517	35.554
3.2	7.361	36.298
3.3	7.204	37.027
3.4	7.047	37.739

3.5	6.891	38.436
3.6	6.734	39.117
3.7	6.577	39.783
3.8	6.421	40.433
3.9	6.264	41.067
4	6.107	41.686
4.1	5.951	42.289
4.2	5.794	42.876
4.3	5.637	43.448
4.4	5.481	44.004
4.5	5.324	44.544
4.6	5.167	45.068
4.7	5.011	45.577
4.8	4.854	46.071
4.9	4.697	46.548
5	4.541	47.01
5.1	4.384	47.456
5.2	4.227	47.887
5.3	4.071	48.302
5.4	3.914	48.701
5.5	3.757	49.085
5.6	3.601	49.453
5.7	3.444	49.805
5.8	3.287	50.142
5.9	3.131	50.463
6	2.981	50.768
6.1	2.897	51.062
6.2	2.813	51.348
6.3	2.729	51.625
6.4	2.645	51.894
6.5	2.561	52.154
6.6	2.477	52.406
6.7	2.393	52.649
6.8	2.309	52.884
6.9	2.225	53.111
7	2.141	53.33
7.1	2.057	53.539
7.2	1.973	53.741
7.3	1.889	53.934
7.4	1.805	54.119

7.5	1.721	54.295
7.6	1.636	54.463
7.7	1.552	54.622
7.8	1.468	54.774
7.9	1.384	54.916
8	1.3	55.051
8.1	1.216	55.176
8.2	1.132	55.294
8.3	1.048	55.403
8.4	.964	55.504
8.5	.88	55.596
8.6	.796	55.68
8.7	.712	55.755
8.8	.628	55.822
8.9	.544	55.881
9	.46	55.931
9.1	.710	55.99
9.2	.614	56.056
9.3	.518	56.113
9.4	.422	56.16
9.5	.326	56.197
9.6	.23	56.225
9.7	.134	56.243
9.8	.038	56.252

TEST 4

6 O'CLOCK LEG, DISTANCE 70 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	6.79	0
.1	6.425	.66
.2	5.744	1.269
.3	5.414	1.827
.4	5.356	2.365
.5	5.299	2.898
.6	5.241	3.425
.7	5.184	3.946
.8	5.127	4.462
.9	5.069	4.972
1	5.012	5.476
1.1	4.955	5.974
1.2	4.897	6.467
1.3	4.84	6.954
1.4	4.782	7.435
1.5	4.725	7.91
1.6	4.668	8.38
1.7	4.61	8.844
1.8	4.553	9.302
1.9	4.496	9.755
2	4.438	10.201
2.1	4.381	10.642
2.2	4.323	11.078
2.3	4.266	11.507
2.4	4.209	11.931
2.5	4.151	12.349
2.6	4.094	12.761
2.7	4.036	13.168
2.8	3.979	13.569
2.9	3.922	13.964
3	3.864	14.353
3.1	3.807	14.737
3.2	3.75	15.115
3.3	3.692	15.487
3.4	3.635	15.853

3.5	3.577	16.214
3.6	3.52	16.569
3.7	3.463	16.918
3.8	3.405	17.261
3.9	3.348	17.599
4	3.291	17.931
4.1	3.233	18.257
4.2	3.176	18.578
4.3	3.118	18.893
4.4	3.061	19.202
4.5	3.004	19.505
4.6	2.946	19.802
4.7	2.889	20.094
4.8	2.832	20.38
4.9	2.774	20.661
5	2.717	20.935
5.1	2.659	21.204
5.2	2.602	21.467
5.3	2.545	21.725
5.4	2.487	21.976
5.5	2.43	22.222
5.6	2.372	22.462
5.7	2.315	22.697
5.8	2.258	22.925
5.9	2.2	23.148
6.	2.143	23.366
6.1	2.086	23.577
6.2	2.028	23.783
6.3	1.985	23.984
6.4	1.956	24.181
6.5	1.926	24.375
6.6	1.897	24.566
6.7	1.868	24.754
6.8	1.839	24.94
6.9	1.81	25.122
7	1.78	25.302
7.1	1.751	25.478
7.2	1.722	25.652
7.3	1.693	25.823
7.4	1.664	25.991

7.5	1.634	26.156
7.6	1.605	26.318
7.7	1.576	26.477
7.8	1.547	26.633
7.9	1.518	26.786
8	1.488	26.937
8.1	1.459	27.084
8.2	1.43	27.229
8.3	1.401	27.37
8.4	1.372	27.509
8.5	1.342	27.645
8.6	1.313	27.778
8.7	1.284	27.907
8.8	1.255	28.034
8.9	1.226	28.158
9	1.196	28.28
9.1	1.167	28.398
9.2	1.138	28.513
9.3	1.109	28.626
9.4	1.08	28.735
9.5	1.05	28.842
9.6	1.021	28.945
9.7	.992	29.046
9.8	.963	29.144
9.9	.934	29.239
10	.901	29.33
10.1	.875	29.419
10.2	.846	29.506
10.3	.817	29.589
10.4	.787	29.669
10.5	.758	29.746
10.6	.729	29.821
10.7	.7	29.892
10.8	.671	29.961
10.9	.641	30.027
11	.612	30.089
11.1	.583	30.149
11.2	.554	30.206
11.3	.525	30.26
11.4	.495	30.311

11.5	.466	30.359
11.6	.437	30.404
11.7	.408	30.447
11.8	.379	30.486
11.9	.349	30.522
12	.32	30.556
12.1	.291	30.587
12.2	.262	30.614
12.3	.233	30.639
12.4	.203	30.661
12.5	.174	30.68
12.6	.145	30.696
12.7	.116	30.709
12.8	.077	30.719

TEST 6

In this test, both the CO and the N_2O was pressure-forced into the thin walled aluminum test tanks simultaneously. It was estimated from previous calibration runs, that, approximately 6 in. (180 lbs) of liquid CO and approximately 6 in. (270 lbs) of N_2O remained in the tank after fueling. The resulting mixture of propellants was detonated two seconds after completion of the fueling operation by two blasting caps placed in the side of the test tank. The digitized data for this test follows:

TEST 6

2 O'CLOCK LEG, DISTANCE 25 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	32.4	0
.1	25.62	2.901
.2	20.6	5.212
.3	21.229	7.303
.4	20.487	9.389
.5	19.745	11.4
.6	19.003	13.338
.7	18.261	15.201
.8	17.519	16.99
.9	18.02	18.767
1	15.835	20.46
1.1	15.187	22.011
1.2	14.539	23.497
1.3	13.892	24.919
1.4	13.244	26.276
1.5	12.596	27.568
1.6	11.948	28.795
1.7	11.301	29.958
1.8	10.653	31.055
1.9	9.844	32.08
2	8.658	33.005
2.1	7.472	33.812
2.2	6.286	34.5
2.3	5.1	35.069
2.4	3.913	35.52
2.5	2.727	35.852
2.6	1.541	36.065
2.7	.355	36.16

TEST 6

2 O'CLOCK LEG, DISTANCE 40 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	9.74	0
.1	8.815	.927
.2	7.89	1.763
.3	7.591	2.537
.4	9.8	3.406
.5	7.887	4.291
.6	8.873	5.129
.7	8.607	6.003
.8	8.341	6.85
.9	8.076	7.671
1	7.81	8.465
1.1	7.544	9.233
1.2	7.279	9.974
1.3	7.013	10.689
1.4	6.747	11.377
1.5	6.481	12.038
1.6	6.216	12.673
1.7	5.95	13.282
1.8	5.684	13.863
1.9	5.418	14.419
2	5.153	14.947
2.1	4.887	15.449
2.2	4.621	15.925
2.3	4.356	16.374
2.4	4.496	16.816
2.5	4.504	17.266
2.6	4.224	17.703
2.7	4.142	18.121
2.8	4.06	18.531
2.9	3.978	18.933
3	3.896	19.327
3.1	3.814	19.713
3.2	3.732	20.09
3.3	3.65	20.459
3.4	3.569	20.82

3.5	3.487	21.173
3.6	3.405	21.518
3.7	3.323	21.854
3.8	3.241	22.182
3.9	3.159	22.502
4	3.077	22.814
4.1	2.995	23.118
4.2	2.913	23.413
4.3	2.831	23.7
4.4	2.749	23.979
4.5	2.667	24.25
4.6	2.585	24.513
4.7	2.503	24.768
4.8	2.422	25.014
4.9	2.34	25.252
5	2.258	25.482
5.1	2.176	25.704
5.2	2.094	25.917
5.3	2.012	26.122
5.4	1.93	26.32
5.5	1.848	26.509
5.6	1.766	26.689
5.7	1.684	26.862
5.8	1.602	27.026
5.9	.773	27.145
6	.74	27.221
6.1	.707	27.293
6.2	.674	27.362
6.3	.641	27.428
6.4	.608	27.49
6.5	.575	27.55
6.6	.542	27.605
6.7	.508	27.658
6.8	.475	27.707
6.9	.442	27.753
7	.409	27.796
7.1	.376	27.835
7.2	.343	27.871
7.3	.31	27.904
7.4	.277	27.933

7.5	.244	27.959
7.6	.211	27.982
7.7	.178	28.002
7.8	.145	28.018
7.9	.112	28.031
8	.079	28.04
8.1	.046	28.047
8.2	.013	28.05

TEST 6

2 O'CLOCK LEG, DISTANCE 70 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	3.92	0
.1	3.609	.376
.2	3.298	.721
.3	3.254	1.049
.4	3.443	1.384
.5	3.041	1.708
.6	3.125	2.016
.7	3.209	2.333
.8	3.293	2.658
.9	3.377	2.992
1	3.461	3.334
1.1	3.544	3.684
1.2	3.284	4.026
1.3	2.875	4.334
1.4	2.626	4.609
1.5	2.748	4.877
1.6	2.87	5.158
1.7	2.975	5.451
1.8	2.928	5.746
1.9	2.881	6.036
2	2.834	6.322
2.1	2.787	6.603
2.2	2.74	6.88
2.3	2.693	7.151
2.4	2.646	7.418
2.5	2.599	7.681
2.6	2.552	7.938
2.7	2.505	8.191
2.8	2.458	8.439
2.9	2.411	8.683
3	2.364	8.922
3.1	2.317	9.156
3.2	2.27	9.385
3.3	2.223	9.61
3.4	2.176	9.83

3.5	2.13	10.045
3.6	2.083	10.256
3.7	2.036	10.462
3.8	1.989	10.663
3.9	1.942	10.86
4	1.895	11.052
4.1	1.848	11.239
4.2	1.801	11.421
4.3	1.754	11.599
4.4	1.707	11.772
4.5	1.66	11.941
4.6	1.613	12.104
4.7	1.768	12.274
4.8	1.739	12.449
4.9	1.711	12.621
5	1.682	12.791
5.1	1.653	12.958
5.2	1.624	13.122
5.3	1.596	13.283
5.4	1.567	13.441
5.5	1.538	13.596
5.6	1.509	13.749
5.7	1.481	13.898
5.8	1.452	14.045
5.9	1.423	14.189
6	1.394	14.33
6.1	1.366	14.468
6.2	1.337	14.603
6.3	1.308	14.735
6.4	1.279	14.865
6.5	1.251	14.991
6.6	1.222	15.115
6.7	1.193	15.236
6.8	1.164	15.353
6.9	1.136	15.468
7	1.107	15.581
7.1	1.078	15.69
7.2	1.049	15.796
7.3	1.021	15.9
7.4	.992	16.001

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7.5	.963	16.098
7.6	.934	16.193
7.7	.906	16.285
7.8	.877	16.374
7.9	.848	16.461
8	.819	16.544
8.1	.791	16.625
8.2	.762	16.702
8.3	.733	16.777
8.4	.704	16.849
8.5	.676	16.918
8.6	.647	16.984
8.7	.618	17.048
8.8	.589	17.108
8.9	.561	17.165
9	.532	17.22
9.1	.503	17.272
9.2	.474	17.321
9.3	.446	17.367
9.4	.417	17.41
9.5	.45	17.453
9.6	.485	17.5
9.7	.461	17.548
9.8	.438	17.593
9.9	.414	17.635
10	.39	17.675
10.1	.366	17.713
10.2	.342	17.749
10.3	.319	17.782
10.4	.295	17.813
10.5	.271	17.841
10.6	.247	17.867
10.7	.223	17.89
10.8	.2	17.912
10.9	.176	17.93
11	.152	17.947
11.1	.128	17.961
11.2	.104	17.973
11.3	.08	17.982
11.4	.057	17.989
11.5	.033	17.993
11.6	.009	17.995

TEST 6

2 O'CLOCK LEG, DISTANCE 140 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	1.54	0
.1	1.463	.15
.2	1.304	.288
.3	1.365	.421
.4	1.439	.562
.5		
.5	1.426	.705
.6	1.413	.847
.7	1.399	.988
.8	1.386	1.127
.9	1.373	1.265
1	1.36	1.402
1.1	1.347	1.537
1.2	1.334	1.671
1.3	1.32	1.804
1.4	1.307	1.935
1.5	1.294	2.065
1.6	1.281	2.194
1.7	1.268	2.322
1.8	1.255	2.448
1.9	1.241	2.573
2	1.228	2.696
2.1	1.215	2.818
2.2	1.202	2.939
2.3	1.189	3.059
2.4	1.176	3.177
2.5	1.162	3.294
2.6	1.149	3.41
2.7	1.136	3.524
2.8	1.088	3.635
2.9	1.069	3.743
3	1.051	3.849
3.1	1.033	3.954
3.2	1.015	4.056
3.3	.996	4.157
3.4	.978	4.255

3.5	.96	4.352
3.6	.942	4.448
3.7	.923	4.541
3.8	.905	4.632
3.9	.887	4.722
4	.869	4.81
4.1	.868	4.897
4.2	.886	4.984
4.3	.904	5.074
4.4	.906	5.165
4.5	.901	5.255
4.6	.897	5.345
4.7	.892	5.434
4.8	.887	5.523
4.9	.882	5.612
5	.877	5.7
5.1	.873	5.787
5.2	.868	5.875
5.3	.863	5.961
5.4	.858	6.047
5.5	.853	6.133
5.6	.838	6.217
5.7	.778	6.298
5.8	.731	6.374
5.9	.737	6.447
6	.743	6.521
6.1	.749	6.596
6.2	.755	6.671
6.3	.761	6.747
6.4	.767	6.823
6.5	.774	6.901
6.6	.78	6.978
6.7	.786	7.057
6.8	.785	7.135
6.9	.773	7.213
7	.76	7.29
7.1	.748	7.365
7.2	.736	7.44
7.3	.724	7.513
7.4	.712	7.584

7.5	.7	7.655
7.6	.688	7.725
7.7	.676	7.793
7.8	.664	7.86
7.9	.652	7.926
8	.64	7.99
8.1	.627	8.054
8.2	.615	8.116
8.3	.603	8.177
8.4	.591	8.237
8.5	.579	8.295
8.6	.567	8.353
8.7	.555	8.409
8.8	.543	8.464
8.9	.531	8.517
9	.519	8.57
9.1	.506	8.621
9.2	.494	8.671
9.3	.482	8.72
9.4	.47	8.768
9.5	.458	8.814
9.6	.446	8.86
9.7	.434	8.904
9.8	.422	8.946
9.9	.41	8.988
10	.398	9.028
10.1	.386	9.068
10.2	.47	9.11
10.3	.461	9.157
10.4	.453	9.203
10.5	.445	9.248
10.6	.437	9.292
10.7	.429	9.335
10.8	.42	9.378
10.9	.412	9.419
11	.404	9.46
11.1	.396	9.5
11.2	.388	9.54
11.3	.38	9.578
11.4	.371	9.616

11.5	.363	9.652
11.6	.355	9.688
11.7	.347	9.724
11.8	.339	9.758
11.9	.331	9.791
12	.322	9.824
12.1	.314	9.856
12.2	.306	9.887
12.3	.298	9.917
12.4	.29	9.947
12.5	.282	9.975
12.6	.273	10.003
12.7	.265	10.03
12.8	.257	10.056
12.9	.249	10.082
3	.241	10.106
13.1	.232	10.13
13.2	.224	10.153
13.3	.216	10.175
13.4	.208	10.196
13.5	.2	10.216
13.6	.192	10.236
13.7	.183	10.255
13.8	.175	10.273
13.9	.167	10.29
14	.159	10.306
14.1	.151	10.322
14.2	.143	10.337
14.3	.134	10.35
14.4	.126	10.364
14.5	.118	10.370
14.6	.11	10.387
14.7	.102	10.398
14.8	.094	10.403
14.9	.085	10.417
15	.077	10.425

TEST 6

6 O'CLOCK LEG, DISTANCE 7.5 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	66	0
.1	58.666	6.233
.2	32	10.766
.3	32	13.966
.4	32	17.166
.5	14.571	19.495
.6	13.142	20.88
.7	11.714	22.123
.8	10.285	23.223
.9	11	24.288
1	17.5	25.713

TEST 6

6 O'CLOCK LEG, DISTANCE 13 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	52.1	0
.1	28	4.005
.2	24.26	6.618
.3	9.742	8.318
.4	11.847	9.397
.5	13.952	10.687
.6	16.057	12.188
.7	29.863	14.484
.8	15.71	16.762
.9	14.765	18.286
1	13.82	19.716
1.1	12.875	21.05
1.2	11.93	22.291
1.3	10.985	23.437
1.4	10.04	24.488
1.5	9.095	25.445
1.6	8.15	26.307
1.7	8.16	27.123
1.8	15.765	28.319
1.9	14.417	29.828
2	13.07	31.202
2.1	11.722	32.442
2.2	10.375	33.547
2.3	9.027	34.517
2.4	7.68	35.353
2.5	6.333	36.053
2.6	4.985	36.619
2.7	3.638	37.05
2.8	2.29	37.347
2.9	.943	37.508

TEST 6

6 O'CLOCK LEG, DISTANCE 25 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	24.7	0
.1	20.922	2.281
.2	18.275	4.24
.3	19.224	6.115
.4	18.785	8.016
.5	18.346	9.873
.6	17.908	11.685
.7	17.469	13.454
.8	17.03	15.179
.9	16.591	16.86
1	16.152	18.497
1.1	15.713	20.091
1.2	15.275	21.64
1.3	14.836	23.146
1.4	14.397	24.608
1.5	13.958	26.025
1.6	13.519	27.399
1.7	13.081	28.729
1.8	12.642	30.015
1.9	12.203	31.258
2	11.764	32.456
2.1	11.325	33.611
2.2	10.886	34.721
2.3	10.448	35.788
2.4	10.009	36.811
2.5	9.57	37.79
2.6	9.131	38.725
2.7	10.693	39.716
2.8	10.281	40.765
2.9	9.869	41.773
3	9.457	42.739
3.1	9.044	43.664
3.2	8.632	44.548
3.3	8.22	45.39
3.4	7.807	46.192

3.5	7.395	46.952
3.6	6.983	47.671
3.7	6.571	48.349
3.8	6.243	48.989
3.9	6.675	49.635
4	7.106	50.324
4.1	7.538	51.057
4.2	7.97	51.832
4.3	7.868	52.624
4.4	7.537	53.394
4.5	7.207	54.132
4.6	6.876	54.836
4.7	6.546	55.507
4.8	6.215	56.145
4.9	5.884	56.75
5	5.554	57.322
5.1	5.223	57.861
5.2	4.893	58.367
5.3	4.562	58.84
5.4	4.231	59.279
5.5	3.901	59.686
5.6	3.57	60.06
5.7	3.24	60.4
5.8	2.909	60.708
5.9	2.578	60.982
6	2.248	61.223
6.1	1.917	61.432
6.2	1.586	61.607
6.3	1.256	61.749
6.4	.925	61.858
6.5	.595	61.934
6.6	.264	61.977

TEST 6

6 O'CLOCK LEG, DISTANCE 40 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	8.6	0
.1	8.126	.836
.2	7.652	1.625
.3	7.178	2.366
.4	6.704	3.06
.5	6.23	3.707
.6	6.99	4.368
.7	6.762	5.056
.8	6.95	5.741
.9	7.187	6.448
1	7.021	7.159
1.1	6.855	7.852
1.2	6.689	8.53
1.3	6.523	9.19
1.4	6.357	9.834
1.5	6.192	10.462
1.6	6.026	11.073
1.7	5.86	11.667
1.8	5.694	12.245
1.9	5.528	12.806
2	5.362	13.351
2.1	5.196	13.879
2.2	5.031	14.39
2.3	4.865	14.885
2.4	4.699	15.363
2.5	4.663	15.831
2.6	4.846	16.307
2.7	4.792	16.789
2.8	4.738	17.265
2.9	4.683	17.736
3	4.629	18.202
3.1	4.575	18.662
3.2	4.52	19.117
3.3	4.466	19.566
3.4	4.412	20.01

3.5	4.358	20.449
3.6	4.303	20.882
3.7	4.249	21.31
3.8	4.195	21.732
3.9	4.141	22.149
4	4.086	22.56
4.1	4.032	22.966
4.2	3.978	23.367
4.3	3.923	23.762
4.4	3.869	24.151
4.5	3.815	24.536
4.6	3.761	24.914
4.7	3.706	25.288
4.8	3.652	25.656
4.9	3.598	26.018
5	3.546	26.376
5.1	3.493	26.728
5.2	3.44	27.074
5.3	3.388	27.416
5.4	3.335	27.752
5.5	3.282	28.083
5.6	3.23	28.408
5.7	3.177	28.729
5.8	3.124	29.044
5.9	3.071	29.354
6	3.019	29.658
6.1	2.966	29.958
6.2	2.913	30.252
6.3	2.861	30.54
6.4	2.808	30.824
6.5	2.755	31.102
6.6	2.703	31.375
6.7	2.65	31.643
6.8	2.597	31.905
6.9	2.545	32.162
7	2.492	32.414
7.1	2.439	32.661
7.2	2.386	32.902
7.3	2.334	33.138
7.4	2.281	33.369

7.5	2.228	33.595
7.6	2.176	33.815
7.7	2.123	34.03
7.8	2.07	34.239
7.9	2.018	34.444
8	1.965	34.643
8.1	1.912	34.837
8.2	1.86	35.026
8.3	1.807	35.209
8.4	1.754	35.387
8.5	1.701	35.56
8.6	1.649	35.728
8.7	1.596	35.89
8.8	1.543	36.047
8.9	1.491	36.199
9	1.438	36.345
9.1	1.385	36.486
9.2	1.333	36.622
9.3	1.28	36.753
9.4	1.227	36.878
9.5	1.175	36.998
9.6	1.122	37.113
9.7	1.069	37.223
9.8	1.016	37.327
9.9	.964	37.426
10	.911	37.52
10.1	.858	37.609
10.2	.806	37.692
10.3	.753	37.77
10.4	.7	37.843
10.5	.648	37.91
10.6	.595	37.972
10.7	.542	38.029
10.8	.49	38.082
10.9	.437	38.127
11	.384	38.168
11.1	.331	38.204
11.2	.279	38.235
11.3	.226	38.26
11.4	.173	38.28

MPS 7309

11.5	.121	38.295
11.6	.068	38.3υ4
11.7	.015	38.308

TEST 6

6 O'CLOCK LEG, DISTANCE 70 FEET

TIME (msec)	PRESSURE (psi)	IMPULSE (psi-msec)
0	3.57	0
.1	3.303	.34?
.2	3.036	.66
.3	2.984	.961
.4	2.955	1.258
.5	2.927	1.552
.6	2.898	1.844
.7	2.87	2.132
.8	2.841	2.418
.9	2.813	2.7
1	2.784	2.98
1.1	2.755	3.257
1.2	2.727	3.531
1.3	2.698	3.803
1.4	2.67	4.071
1.5	2.641	4.337
1.6	2.613	4.6
1.7	2.584	4.86
1.8	8.556	5.117
1.9	2.527	5.371
2	2.499	5.622
2.1	2.47	5.871
2.2	2.441	6.116
2.3	2.413	6.359
2.4	2.384	6.599
2.5	2.356	6.836
2.6	2.327	7.07
2.7	2.299	7.301
2.8	2.27	7.53
2.9	2.242	7.756
3	2.213	7.978
3.1	2.185	8.198
3.2	2.156	8.415
3.3	2.127	8.63
3.4	2.099	8.841

3.5	2.07	9.049
3.6	2.042	9.255
3.7	2.013	9.458
3.8	1.985	9.658
3.9	1.956	9.855
4	1.928	10.049
4.1	1.899	10.241
4.2	1.871	10.429
4.3	1.842	10.615
4.4	1.813	10.798
4.5	1.785	10.978
4.6	1.756	11.155
4.7	1.728	11.329
4.8	1.699	11.5
4.9	1.671	11.669
5	1.642	11.835
5.1	1.614	11.998
5.2	1.585	12.157
5.3	1.557	12.315
5.4	1.528	12.469
5.5	1.499	12.62
5.6	1.471	12.769
5.7	1.628	12.924
5.8	1.608	13.086
5.9	1.588	13.246
6	1.568	13.403
6.1	1.549	13.559
6.2	1.529	13.713
6.3	1.509	13.865
6.4	1.489	14.015
6.5	1.47	14.163
6.6	1.45	14.309
6.7	1.43	14.453
6.8	1.411	14.595
6.9	1.391	14.735
7	1.371	14.874
7.1	1.351	15.01
7.2	1.332	15.144
7.3	1.312	15.276
7.4	1.292	15.406

7.5	1.272	15.535
7.6	1.253	15.661
7.7	1.233	15.785
7.8	1.213	15.908
7.9	1.194	16.028
8	1.174	16.147
8.1	1.154	16.263
8.2	1.134	16.377
8.3	1.115	16.49
8.4	1.095	16.6
8.5	1.075	16.709
8.6	1.055	16.816
8.7	1.032	16.92
8.8	1.007	17.022
8.9	.982	17.121
9	.957	17.218
9.1	.932	17.313
9.2	.907	17.405
9.3	.881	17.494
9.4	.856	17.581
9.5	.831	17.666
9.6	.806	17.748
9.7	.781	17.827
9.8	.756	17.904
9.9	.731	17.978
10	.706	18.05
10.1	.681	18.12
10.2	.656	18.187
10.3	.631	18.251
10.4	.606	18.313
10.5	.581	18.372
10.6	.555	18.429
10.7	.53	18.483
10.8	.505	18.535
10.9	.48	18.585
11	.455	18.631
11.1	.43	18.676
11.3	.38	18.757
11.4	.355	18.794

11.5	.33	18.828
11.6	.305	18.86
11.7	.28	18.889
11.8	.255	18.916
11.9	.234	18.94
12	.222	18.963
12.1	.209	18.985
12.2	.196	19.005
12.3	.184	19.024
12.4	.171	19.042
12.5	.158	19.058
12.6	.146	19.073
12.7	.133	19.087
12.8	.12	19.1
12.9	.107	19.112
13	.095	19.122
13.1	.082	19.131
13.2	.069	19.138
13.3	.057	19.145
13.4	.044	19.15
13.5	.031	.9.153
13.6	.019	19.156
13.7	.006	19.157